Iron and Steel Engineer

Established 1907 as Proceedings of A. I. & S. E. E.

J. F. KELLY, EDITOR

CONTENTS

Volume IX. MAY, 1932. Number V.

A. I. & S. E. E. Convention and Exposition Plans 197

Recent Improvements in Wet Method of Cleaning Blast Furnace Gas—by Robert R. Harmon, Chemical Engineer, Peabody Engineering Co., New York, N. Y. 200

Natural Gas in Steel Plants—by Carl Emmerling, Fuel Engineer, East Ohio Gas Company, Cleveland, Ohio 204

The "Combination System"—by R. J. Wean, President, Wean Engineering Company, Warren, Ohio 207

The Combination Method—by H. Melin, Engineer, Aetna-Standard Engineering Company, Youngstown, Ohio 211

Continuous Heating Furnaces—by H. P. McCann, McCann Engineering Corp., Cleveland, Ohio—presented by R. L. Corbett, McCann Engineering Corp., Pittsburgh, Pa. 213

Continuous Sheet Mill Furnaces—by A. L. Hollinger, Engineer, Surface Combustion Corporation, Toledo, Ohio 216

The Application of Electric Control Equipment to Roller's and Catcher's Tables—by J. J. Mellon, Engineer, Clark Controller Co., Cleveland, Ohio 218

The Squirrel-Cage Induction Motor As Applied to Starting, Reversing and Stopping Duty—by E. W. Henderson, Design Engineer, Reliance Electric & Engineering Company, Cleveland, Ohio 222

Developments in Electric Motors and Magnetic Controllers to Handle Mechanical Processes in Sheet and Tin Mills—by G. A. Caldwell, General Engineer, Westinghouse Electric and Mfg. Co., East Pittsburgh, Pa. 229

Motors and Control for Automatic Sheet Catchers—by W. B. Snyder, Industrial Engineering Department, General Electric Co., Schenectady, N. Y. 234

Discussion—Papers Presented at Spring Conference, Combustion Engineering Division of the A. I. & S. E. E.—discussion presented by H. M. Pier, G. T. Hollett, B. W. Norton, W. J. McGurty, R. R. Harmon, J. L. Miller, C. Emmerling, H. H. Holloway, C. J. Daley, L. Larson, J. A. Hunter, R. J. Wean, R. O. Herbig, H. Melin, J. H. Van Campen, F. E. Leahy, T. J. Ess, R. L. Corbett, A. L. Hollinger, F. J. Burd, A. M. MacCutcheon, W. B. Shirk, G. R. Carroll, J. J. Mellon, G. A. Caldwell, E. W. Henderson, W. B. Snyder 237

Discussion—The Squirrel-Cage Induction Motor as Applied to Starting, Reversing and Stopping Duty—discussion presented March 19th, 1932, at Pittsburgh, Pa., by W. Anderson, J. W. Bates, D. I. Bohn, E. W. Henderson, J. I. Kaspari, W. B. Shirk, C. O. Franklin 243

Items of Interest 246

Preliminary Calendar of Events II

Editorial III

Index to Advertisers IV

Published Monthly by

Association of Iron and Steel Electrical Engineers

BOARD OF DIRECTORS—1931-1932

President, J. J. BOOTH, Electrical Supt., National Tube Company, Gary, Ind.

1st Vice Pres., J. D. Donovan, Electrical & Mechanical Supt., Republic Steel Corporation, Massillon, Ohio.

2nd Vice Pres., W. E. Miller, Electrical Supt., Bethlehem Steel Company, Johnstown, Pa.

Treasurer, W. H. Burr, Electrical Supt., Lukens Steel Company, Coatesville, Pa.

Secretary, William Jackson, Electrical Supt., Homestead Works, Carnegie Steel Company, Munhall, Pa.

Past Pres., F. O. Schnure, Electrical Supt., Bethlehem Steel Company, Sparrows Point, Md.

Past Pres., F. W. Cramer, Chief Electrical Engineer, Republic Steel Corporation, Youngstown, Ohio.

Director at Large, J. H. Van Campen, Chief Engineer of Youngstown District, Republic Steel Corporation, Youngstown, Ohio.

Honorary Director, James Farrington, Electrical Supt., Wheeling Steel Corporation, Steubenville, Ohio.

Director, J. H. Wagner, Electrical Supt., Acme Steel Company, Chicago, Illinois.

Director, K. M. Raynor, Electrical Supt., Bethlehem Steel Company, Bethlehem, Pa.

Director, Birger Thele, Electrical Dept., Tennessee Coal Iron & R. R. Company, Fairfield, Ala.

Director, J. A. Clauss, Chief Engineer, Great Lakes Steel Corporation, Detroit, Mich.

Director, G. R. Carroll, Electrical Supt., Jones & Laughlin Steel Corporation, Aliquippa, Pa.

Director, C. C. Pecu, Lubrication Engineer, Bethlehem Steel Company, Lackawanna, N. Y.

Director, G. T. Hollett, Combustion Engineer, Illinois Steel Company, South Chicago, Ill.

Director, J. F. Hunter, Safety Engineer, Carnegie Steel Company, Pittsburgh, Pa.

Honorary Director, E. Friedlander, Pittsburgh, Pa.

Managing Director, John F. Kelly, Empire Building, Pittsburgh, Pa.

Entered as second-class matter January 25th, 1924, at Pittsburgh, Pa., under the Act of March 3rd, 1879.
Subscription Price $5.00 per Year. Single Copy $1.00.

Preliminary Calendar of Events

AT

Association of Iron and Steel Electrical Engineers

CONVENTION AND EXPOSITION

JUNE 20-23, 1932 – PITTSBURGH, PA.

WILLIAM PENN HOTEL

MONDAY, JUNE 20, 1932

Business Session. Electrical Developments. Welding. The Substitution of Fabricated Steel for Castings. High Tension Power Line Safety. Opening of the Iron and Steel Exposition. Informal Reception at William Penn Hotel.

TUESDAY, JUNE 21, 1932

Standardized Control Apparatus. Devices Actuated by Light. Ladle Crane Practice in the Iron and Steel Industry.

WEDNESDAY, JUNE 22, 1932

Design and Performance of a Fully Compensated D.C. Machine and What it means to the Iron and Steel Industry. Determination of Motor Capacity for Main Roll Drives. Development of Air Cooled and Insulated Refractory Walls. Water Cooled Furnaces for Steam Boilers. The Influence of Atmosphere and Temperature on the Behavior of Steel with Respect to Scale Losses. Maintenance and Care of Recording Instruments Used in the Steel Industry. Fuel Economy Under Curtailed Operating Conditions. Higher Steam Pressures in the Blast Furnace-Steel Mill Power Plants.

THURSDAY, JUNE 23, 1932

Mechanical Transmission of Power. Lubrication and Lubricants for Roll Necks. The Application of Micarta, Batex, Celeron, and Synthane Bearings to Roll Necks. Questions and Answers in Connection with Lubrication as Applied to Steel Mill Equipment. Formal Reception.

IRON & STEEL EXPOSITION

WILLIAM PENN HOTEL

JUNE 20-23, 1932

Open Monday, 1:30 P. M.	Closes 10:00 P. M.
Open Tuesday, 1:30 P. M.	Closes 10:00 P. M.
Open Wednesday, 1:30 P. M.	Closes 10:00 P. M.
Open Thursday, 1:30 P. M.	Closes 10:00 P. M.

EDITORIAL

1932 Steel Convention and Exposition

IF there ever was a time in the history of the Iron and Steel Industry when a clearer understanding of actual conditions (plus a thorough knowledge of the best methods of operating Steel Plants to meet the present economic crisis) was more necessary than at the present time, the Association of Iron & Steel Electrical Engineers is not aware of it.

It would seem to us that it is precisely in times like these that a Convention and Exposition can be of the most value to the Steel Industry and its operating personnel.

A Convention is a forum for the frank exchange of ideas, methods and systems:

1. Regarding equipment now used.
2. Regarding contemplated new equipment.
3. Regarding operating methods now used.
4. Regarding contemplated new methods to be used.

All for one purpose—to assist in the economic production of Steel.

An Exposition such as the Association conducts is for this purpose:

1. A practical demonstration of improvements in apparatus now in use in the Steel Industry.
2. A practical demonstration of entirely new developments in apparatus to be used to process and produce Steel.
3. A common ground where the builder and buyer may exchange opinions first hand on the adaptability of the apparatus being demonstrated to the present type of equipment in use in the Iron and Steel Industry.

There is, in some quarters, a lack of understanding on just what good an association or technical society may do in times like these.

This lack of understanding prompts remarks like these: "Nothing will do any good;" "We will lay low until the depression is over."

What the Industry should do is to say, "Well, this is one year we cannot afford to miss a chance to pick up any new ideas."

Our Association has for its basic purpose a broad vision not only for its own interest, but the interests of those dependent on it, catering to it or dealing with it and for this purpose our Association studies, investigates and makes research into all those factors which may effect the economic stability, growth, prosperity and welfare of the Iron and Steel Industry. Our Convention offers a definite idea-exchange value which every company should be willing and glad to pay for.

The Association of Iron & Steel Electrical Engineers offers to the Steel Industry in its 1932 Convention and Exposition one of the best balanced programs in its history, a program of technical and practical information backed up by authorities who have spent their time, their energy and most of their lives in solving problems applicable to the advancement of engineering and operating problems in the Iron and Steel Industry.

INDEX TO ADVERTISERS

A

Aetna-Standard Engineering Co. 266
The Alliance Machine Company 280
Allis-Chalmers Manufacturing Co. 270
Aluminum Company of America 251

B

The Baker-Raulang Company 262
The Bartlett Hayward Company 255
E. W. Bliss Co. 269
Bull Dog Electric Products Company 247

C

Century Electric Company 275
The Clark Controller Co. 284
The Cleveland Crane & Engineering Co. 258
Crocker-Wheeler Electric Manufacturing Co. 256

D

DeLaval Steam Turbine Co. 279
Henry L. Doherty & Company 263

E

The Electric Controller & Mfg. Co. 271
Elliott Company 249

F

Farrel-Birmingham Company, Inc. 283
Flinn & Dreffein Co. 259

G

General Electric Company 250-Cover-4

H

Hyatt Roller Bearing Company 265

I

ITE Circuit Breaker Company Cover-3

J

Jefferson Electric Co. 268

K

Keystone Lubricating Company 254

L

LeCarbone Company 281

M

The Martindale Electric Co. 282
The McKay Machine Co. 259
Morgan Construction Company 252
The Morgan Engineering Company 273
Morganite Brush Co., Inc. 286

N

National Armature & Electric Works 282
The New Departure Mfg. Co. 272
The Nichols-Lintern Company 267

O

The Ohio Electric Mfg. Co. 283

P

Pennsylvania Transformer Company 284

R

Reliance Electric & Engineering Co. 260-61
Rockbestos Products Corporation 274
The Rowan Controller Co. 286

S

Schloemann Engineering Company 288
Shepard Niles Crane & Hoist Corporation 287
SKF Industries, Inc. 277
Stimple & Ward Co., Inc. 285
Sundh Electric Co. 284
Surface Combustion Corporation 263

T

The Thompson Electric Company 281
The Tool Steel Gear & Pinion Co. 280
Turner Engineering Company 257

U

United Engineering and Foundry Company Cover 1

W

The Wean Engineering Co., Inc. 259
The Wellman Engineering Co. 276
Westinghouse Electric & Mfg. Company Cover 2-253-264
Weston Electrical Instrument Corporation 278
Edwin L. Wiegand Company 285

J. J. BOOTH

J. D. DONOVAN

W. E. MILLER

BOARD OF DIRECTORS—1931-1932

President, J. J. Booth, Elec. Supt., National Tube Co., Gary, Ind.

1st Vice Pres., J. D. Donovan, Elec. & Mech. Supt., Republic Steel Corp., Massillon, Ohio.

2nd Vice Pres., W. E. Miller, Elec. Supt., Bethlehem Steel Co., Johnstown, Pa.

Treasurer, Walter H. Burr, Elec. Supt., Lukens Steel Co., Coatesville, Pa.

Secretary, William Jackson, Elec. Supt., Homestead Works, Carnegie Steel Co., Munhall, Pa.

Past Pres., F. O. Schnure, Elec. Supt., Bethlehem Steel Co., Sparrows Point, Md.

Past Pres., F. W. Cramer, Chief Elect. Engr., Republic Steel Corp., Youngstown, Ohio.

Director at Large, J. H. Van Campen, Chief Engr. of Youngstown District, Republic Steel Corp., Youngstown, Ohio.

Director, K. M. Raynor, Electrical Supt., Bethlehem Steel Co., Bethlehem, Pa.

Director, G. T. Hollett, Combustion Engr., Illinois Steel Co., South Chicago, Ill.

Director, G. R. Carroll, Electrical Supt., Jones & Laughlin Steel Corp., Aliquippa, Pa.

Honorary Director, James Farrington, Electrical Supt., Wheeling Steel Corp., Steubenville, Ohio.

Director, C. C. Pecu, Lubrication Engr., Bethlehem Steel Co., Lackawanna, N. Y.

Director, B. Thele, Electrical Dept., Tennessee Coal, Iron & R. R. Co., Fairfield, Ala.

Director, J. F. Hunter, Safety Engr., Carnegie Steel Company, Pittsburgh, Pa.

Director, J. H. Wagner, Electrical Supt., Acme Steel Company, Chicago, Ill.

Director, J. A. Clauss, Chief Engr., Great Lakes Steel Corp., Detroit, Mich.

Honorary Director, E. Friedlander, Pittsburgh, Pa.

Managing Director, John F. Kelly, Empire Building, Pittsburgh, Pa.

A. I. & S. E. E. Convention and Exposition Plans

Plans for the 1932 A. I. & S. E. E. Convention and Iron and Steel Exposition are practically completed. All Divisions of the Association,—Mechanical, Electrical, Lubrication, Combustion and Safety will meet in Pittsburgh at the William Penn Hotel, on June 20th, 21st, 22nd and 23rd. Members from the five Sections, Birmingham, Chicago, Cleveland, Philadelphia and Pittsburgh will be in attendance.

CONVENTION COMMITTEES

J. J. Booth, National President of the Association of Iron and Steel Electrical Engineers, has appointed J. D. Donovan as General Chairman of the Convention and Exposition Committee and he will be assisted by W. E. Miller, W. H. Burr and W. Jackson. Co-operating with the National Executive Officers, the other members of the Board of Directors will direct the activities of other Convention and Exposition Committees. The personnel of these Committees will appear in the June issue of the Iron and Steel Engineer.

TECHNICAL PROGRAM

Under the guidance of the Board of Directors a Convention Program that will be of vital interest to every engineer and executive of the Iron and Steel

and Allied Industries has been prepared. Papers covering Mechanical, Electrical, Lubrication, Combustion and Safety Engineering problems will be presented and discussed by engineers of national repute. Two days will be devoted to papers and discussions on Mechanical and Electrical subjects; one day to Combustion Topics and one day to Lubrication Problems.

IRON AND STEEL EXPOSITION

As in previous years, the Iron and Steel Exposition will be one of the features of the Annual Convention. The object of the Iron and Steel Exposition is to acquaint engineers with the status of the art

General View of 1931 Iron & Steel Exposition in Cleveland, O.

in reference to the various lines of apparatus used in the Industry. Accomplishments by the use of improved devices, new applications, etc., will largely form the subject of the papers and discussions of the Technical Sessions. Technical papers and discussions regarding the improvement of the quality of product and economy of operation develop the urge to make improvements. Exhibits and Expositions develop this urge into a real desire as concrete suggestions and ideas are presented in these equipment displays.

In the Iron and Steel Exposition each year, the manufacturers who service the Iron and Steel Industry are presented an opportunity to display or exhibit the new developments in their products and equipment to the engineers and executives of the Iron and Steel and Allied Industries. It is at the Exposition that the engineers and executives have the opportunity to inspect, examine and have demonstrated to them just what the equipment will do for them in their plants.

REGISTRATION

As usual, all interested engineers and executives are invited to attend and take part in the discussions at the Technical Sessions. Admission to the Iron and Steel Exposition will be by ticket only and these can be secured gratis at the Registration Booth or from Exhibitor's representatives. If tickets are desired in advance by non-members these can be obtained by writing the Association Headquarters.

JUNE CONVENTION ISSUE

The June issue of the Iron and Steel Engineer will be the Convention issue. It will contain some copies of papers to be presented at the Convention as well as complete program, committees and plans for the Convention and Exposition. The Iron and Steel Engineer is the official periodical of the A. I. & S. E. E. and all papers and discussions presented at the Convention will appear in an early issue.

HALF FARE CERTIFICATES

The Central Passenger Association have granted us the use of Identification Certificates, good on most any railroad of the country, entitling our members, dependent members of their families, our exhibitors and their dependents, to a special one and one-half round trip fare (minimum $1.00 fare). Going tickets may be purchased from June 16th to June 22nd, and good for return, beginning June 20th and from thirty days from date of sale (including

General View of 1931 Iron & Steel Exposition in Cleveland, O.

day of sale). All tickets must be validated at the R. R. offices before they can be used on the return trip, and all ticket holders must arrive at their starting point on, or before, midnight of the date of expiration of the ticket. Children of five and under twelve years of age, when accompanied by parent or guardian, under like conditions, will be charged one-half of the fare of the adults. For further information about use of diverse routes consult your local ticket agent. Kindly advise our Association office as to the number of certificates that you will require and they will be promptly forwarded without cost to you.

SPRING CONFERENCE

COMBUSTION ENGINEERING DIVISION

ASSOCIATION OF IRON AND STEEL ELECTRICAL ENGINEERS

MARCH 24, 1932

OHIO HOTEL — **YOUNGSTOWN, OHIO**

▲

PAPERS PRESENTED

"RECENT IMPROVEMENTS IN WET METHOD OF CLEANING BLAST FURNACE GAS," by **R. R. Harmon,** Chemical Engineer, Peabody Engineering Company, New York, N. Y.

"NATURAL GAS IN STEEL PLANTS," by **C. Emmerling,** Fuel Engineer, East Ohio Gas Company, Cleveland, Ohio.

"THE COMBINATION SYSTEM," by **R. J. Wean,** President, Wean Engineering Company, Warren, Ohio.

"THE COMBINATION METHOD," by **H. Melin,** Engineer, Aetna-Standard Engineering Company, Youngstown, Ohio.

"CONTINUOUS HEATING FURNACES," by **H. P. McCann,** McCann Engineering Corporation, Cleveland, Ohio, Associated with the Rust Engineering Company.

"CONTINUOUS SHEET MILL FURNACES," by **A. L. Hollinger,** Engineer, Surface Combustion Corporation, Toledo, Ohio.

"THE APPLICATION OF ELECTRIC CONTROL EQUIPMENT TO ROLLER'S AND CATCHER'S TABLES," by **J. J. Mellon,** Engineer, The Clark Controller Company, Cleveland, Ohio.

"THE SQUIRREL CAGE INDUCTION MOTOR AS APPLIED TO STARTING, REVERSING AND STOPPING DUTY," by **E. W. Henderson,** Design Engineer, Reliance Electric & Engineering Commany, Cleveland, Ohio.

"DEVELOPMENTS IN ELECTRIC MOTORS AND MAGNETIC CONTROLLERS TO HANDLE MECHANICAL PROCESSES IN SHEET AND TIN MILLS," by **G. A. Caldwell,** General Engineer, Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.

"MOTORS AND CONTROL FOR AUTOMATIC SHEET CATCHERS," by **W. B. Snyder,** Industrial Engineering Department, General Electric Company, Schenectady, N. Y.

▲

DISCUSSION PRESENTED BY

H. M. PIER, Engineer, Research Corporation, Chicago, Ill.

W. J. McGURTY, Engineer, Bartlett-Hayward Company, Pittsburgh, Pa.

B. W. NORTON, Superintendent, Blast-Furnaces, Republic Steel Corporation, Youngstown, Ohio.

R. R. HARMON, Chemical Engineer, Peabody Engineering Company, New York, N. Y.

J. L. MILLER, Steam and Fuel Engineer, Carnegie Steel Company, Youngstown, Ohio.

C. EMMERLING, Fuel Engineer, East Ohio Gas Company, Cleveland, Ohio.

H. H. HOLLOWAY, Assistant to President, Apollo Steel Company, Apollo, Pa.

C. J. DALEY, Superintendent of Sheet Mills, Youngstown Sheet & Tube Company, Youngstown, Ohio.

L. LARSON, Chief Engineer, Republic Steel Corporation, Massillon, Ohio.

J. A. HUNTER, Assistant Chief Engineer, American Sheet & Tin Plate Company, Pittsburgh, Pa.

R. J. WEAN, President, Wean Engineering Company, Warren, Ohio.

R. O. HERBIG, Engineer, Reliance Electric & Engineering Company, Chicago, Ill.

J. H. VAN CAMPEN, Chief Engineer, Youngstown District, Republic Steel Corporation, Youngstown, Ohio.

F. E. LEAHY, Fuel Engineer, Youngstown Sheet & Tube Company, Youngstown, Ohio.

G. T. HOLLETT, Combustion Engineer, Illinois Steel Company, South Chicago, Ill.

T. J. ESS, Combustion Engineer, Republic Steel Corporation, Massillon, Ohio.

R. L. CORBETT, Vice President, McCann Engineering Corporation, Associated with the Rust Engineering Company, Pittsburgh, Pa.

A. L. HOLLINGER, Engineer, Surface Combustion Corporation, Toledo, Ohio.

F. J. BURD, Engineer, Cutler-Hammer, Inc., Chicago, Ill.

A. M. MacCUTCHEON, Vice President, Reliance Electric & Engineering Company, Cleveland, Ohio.

W. B. SHIRK, Steel Mill Engineer, Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.

G. R. CARROLL, Electrical Superintendent, Jones & Laughlin Steel Corporation, Aliquippa, Pa.

J. J. MELLON, Engineer, The Clark Controller Company, Cleveland, Ohio.

G. A. CALDWELL, General Engineer, Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.

E. W. HENDERSON, Design Engineer, Reliance Electric & Engineering Company, Cleveland, Ohio.

W. B. SNYDER, Industrial Engineering Department, General Electric Company, Schenectady, N. Y.

Recent Improvements in Wet Method of Cleaning Blast Furnace Gas

By ROBERT R. HARMON
Chemical Engineer, Peabody Engineering Co., New York, N. Y.

Presented before Spring Conference, Combustion Engineering Division of the Association of Iron and Steel Electrical Engineers at Youngstown, O., March, 1932.

During the past several years a great deal of attention and thought have been given to the subject of more intensive cleaning of blast furnace gas, for the reason that a truly clean gas can be utilized with greater efficiency, for many more purposes, and in more refined equipment, than is true of dirty or partially cleaned gas.

All of you here are no doubt familiar with the conventional procedure involved in washing blast furnace gas, and with the distinction between gas having been subjected to primary cleaning and that subjected to secondary cleaning. A brief review of the subject at this point might, however, lead to a better understanding of the factors involved in wet cleaning, the random nature of the treatment it generally receives, and how a natural sequence of steps in scrubbing the gas yields superior results from the standpoint of final dust and moisture content and cost of cleaning.

Primary cleaning in general effects the removal of the great bulk of dust carried forward in the gas after it leaves the dry dust catcher. Along with this there is the extraction of the sensible heat from the gas by direct contact with cooling water, and a partial elimination of water entrained by the gas in the scrubbing and cooling operation. Dust removal is accomplished by direct hitting of the suspended matter by water sprays, or impingement of the former against wetted surfaces from which the deposit is more or less imperfectly removed by the wash water. Primary cleaning, in general, may be expected to yield gas containing about 0.40 grain of dust per cubic foot.

Secondary cleaning has as its aim the removal from the gas of all remaining suspended matter leaving the primary scrubber and which might deposit in equipment. Cold gas from the primary cleaner is mingled with cold water in the secondary scrubber and the mixture is usually subjected to a violent beating action and, at the same time, the influence of centrifugal force. This treatment is accorded for the purpose of wetting and loading the small particles of dust and fume by driving them through the films of water or into the drops of water generated by the above action. In either case the objective is to give the particle sufficient mass to make it susceptible to centrifugal or other forces which insure its removal from the gas stream. Secondary cleaning of this character will, in general, yield gas containing between 0.01 and 0.03 grain of dust per cubic foot.

The really fundamental difference between primary and secondary cleaning lies in the fact that wetting and loading of the dust particles with water is not a difficult problem in primary cleaning, as borne out by the ease with which the bulk of dust is removed by sprays and slight impingement effects. In secondary cleaning the problem is different. If primary cleaning has been thorough, the residual particles of dust are too small to be removed by further spray action, and impingement against baffles at high velocities is also ineffectual in removing them as they carry no water film . Consequently the beating action involved in wetting them must be violent. It should be remembered that the velocity required for sufficient impact between the dust and water film to effect wetting, varies inversely with the mass of the particle. This explains in part why attempts to clean beyond a certain degree have called for great expenditure of power.

From the foregoing we may infer that if some other means of wetting and loading the particles with water except that of violent beating were available, secondary cleaning might be accomplished with much less difficulty. The required velocity of impact would thus be greatly diminished and a different style of apparatus might be employed which could treat much larger volumes of gas at less expense.

The age-old phenomenon of condensation has been employed to effect this desired result, and it is the same natural phenomenon which causes rain. Most of you have no doubt observed the effect of condensation in the form of sludge or slurry dripping from gas mains carrying washed gas. This dirt escaped removal while being subjected to spray and impingement action in the scrubber operation but became wetted and loaded with water by condensation of residual vapor or gas during passage along the mains. The only difference between condensation occurring in nature as in rain formation and condensation as employed industrially in this development lies in the absence of control in the former and the application of control in the latter.

The fact that cooling a saturated gas-vapor mixture below its dew point produces a liquid is too well known to deserve comment. It is perhaps not so well known that the formation of the liquid is induced by the presence of free surfaces suspended in the mixture, which are known as condensation nuclei. Without them a state of supersaturation of vapor would prevail just as with a chemical solution, which will remain in a supersaturated condition until foreign matter contaminates it, whereupon crystallization immediately occurs. These condensation nuclei are actual particles of solid or liquid which individually may escape detection by the naked eye, although they perform a very positive service.

As stated, upon cooling a saturated vapor or gas-vapor mixture below its dew point, condensation is induced by the nuclei present in the mixture, and drops of liquid are formed about the nuclei as centers. Thus by the mere act of cooling the humidified

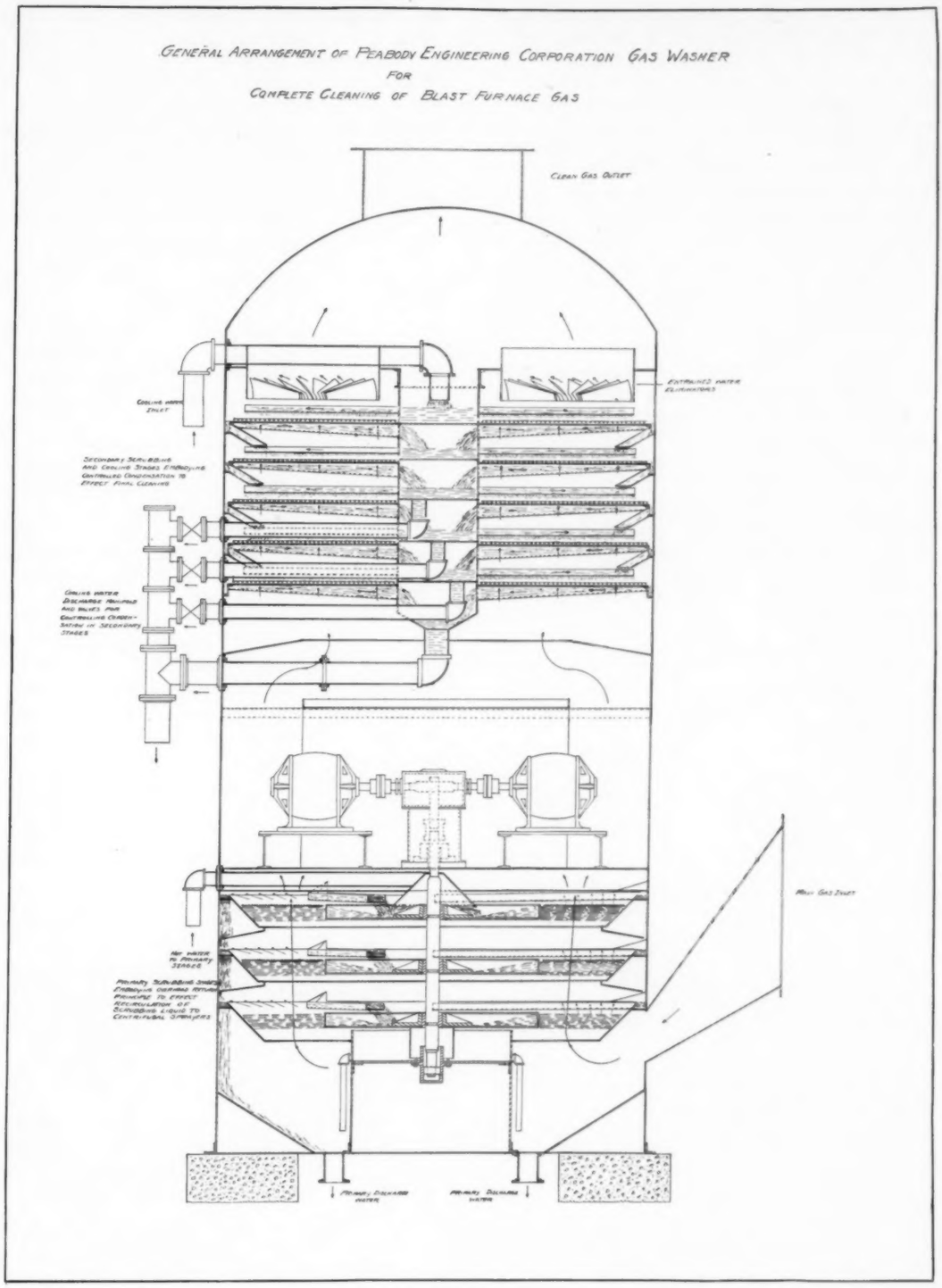

GENERAL ARRANGEMENT OF PEABODY ENGINEERING CORPORATION GAS WASHER
FOR
COMPLETE CLEANING OF BLAST FURNACE GAS
CLEAN GAS OUTLET
ENTRAINED WATER ELIMINATORS
COOLING WATER INLET
SECONDARY SCRUBBING AND COOLING STAGES EFFECTING CONTROLLED CONDENSATION TO EFFECT FINAL CLEANING
COOLING WATER DISCHARGE MANIFOLD AND VALVES FOR CONTROLLING CONDENSATION IN SECONDARY STAGES
RAW GAS INLET
AIR WATER TO PRIMARY STAGES
PRIMARY SCRUBBING STAGES EFFECTING CONTROLLED RETURN PRESSURE TO EFFECT RECIRCULATION OF SCRUBBING LIQUID TO CENTRIFUGAL SEPARATORS
PRIMARY DISCHARGE WATER
PRIMARY DISCHARGE WATER

FIG. 1.

blast furnace gas below its dew point, the particles of dust and fume in the gas receive the vital film of liquid which is required for their removal from the body of the gas.

The action so far described is the same as in the production of rain, wherein condensation occurs in the higher and colder strata of air about nuclei present there, to form droplets. The droplets formed gaining weight, they acquire motion with respect to the air in virtue of gravitational influences. Condensation continues, effecting growth of the droplets, until descent becomes fairly rapid and sizeable drops of water are eventually formed before striking the earth.

Successful application of such a phenomenon to industrial needs calls for a departure from the natural scheme in view of the difference in the respective conditions prevailing in a dust laden gas and in

atmospheric air. As against thousands of particles per cubic inch in air, there are millions in a cubic inch of gas. Furthermore, there is a limit to the quantity of vapor actually required to be condensed on a particle for removal from a gas stream, and in the artificial process this limit need not be exceeded, whereas nature permits a single drop to collect whatever it can during its descent to earth.

In other words, condensation having been started, with the consequent formation of liquid about a dust particle, the droplet formed will continue to grow as long as cooling occurs and vapor is being condensed. Without exerting any control during the cooling of hot gases by contact with water, natural condensation takes place, but in this case the vapor present, which is a valuable constituent, condenses in such a way that much of its usefulness is lost. The mere natural formation of rain drops in the atmosphere, while successfully removing the larger and more easily wetted dust particles or nuclei, falls far short of removing all the dirt in the air. If it did the problem would be less difficult of solution.

A cleaning method based upon the phenomenon of condensation must eliminate the arbitrary elements entering into it. And there must be substituted another sequence of steps in order to attain the desired ends, which has been done in the development presented here.

From the foregoing it will be clear that water vapor can be utilized as a cleaning medium and that aside from the initial quantity in the raw gas, the sensible heat of the gas is also a potential source, if properly transformed.

In cooling the gas its heat is, of course, absorbed by the water, the temperature of the latter rises, and evaporation occurs. The quantity of water evaporated is dependent upon the amount of cooling water used and sensible heat in the raw gas. Any excess beyond the theoretical requirement for cooling the gas lowers the temperature of the discharge water proportionally, and evaporation is retarded disproportionally, as reference to vapor tension curves for water will show. As evaporation is not instantaneous, maximum transformation of sensible heat into latent heat of water vapor will not occur in a single passage of cooling water through the washer, because the water must first receive heat in order to give it up. This is indicated by the rising water temperature throughout the present types of washers from inlet to discharge. Evaporation, on the contrary, exerts a cooling effect on any body of water unless the heat flowing out is balanced by the heat flowing in. Consequently, the water for humidifying the gas and the water for cooling should be kept separate, and the former should be reused after clarification to the degree necessary and returned to the scrubber.

In common practice this is not the case. An excess of cooling water is employed, sensible heat thereby lost with the result that water vapor which could be produced and employed later for removing dust is wasted.

When condensation of water vapor takes place in a dust laden gas, in which both hygroscopic and nonhygroscopic particles in a large range of sizes may be found, as in blast furnace gas, the larger particles and the more easily wetted or hygroscopic ones appear to act as nuclei first and receive vapor to the exclusion of the small particles. Experiments have shown rather clearly that this is the case. Consequently, to insure wetting and removal of the smallest particles by condensation, efficient removal of the larger ones must be accomplished before condensation begins and this is done during the evaporation process. Thus re-use of the hot discharge water insures that the gas will be kept at a temperature above its maximum theoretical dew point, and complete transformation of sensible heat into latent heat and proper elimination of the larger particles are assured. Likewise all of the vapor in the gas is conserved for useful work in the condensing stage of the scrubber, in this improved method for the removal of the smaller particles.

After humidification and primary stripping of the gas has been accomplished, the heat is extracted and condensation of water vapor takes place in a series of stages. By cooling the gas in stages, or interruptedly so to speak, the droplets formed about the dust particles are restricted to a certain size and those formed in each stage are removed from the body of the gas before condensation proceeds. This insures the most efficient utilization of vapor for dust removal by preventing any excess from being condensed on any one class of particles. Actually this amounts to an apportionment of vapor among the various classes of dust and fume particles which require to be wetted and loaded with varying quantities of water vapor for their removal.

The adaptation of this theory to industrial needs required a considerable amount of experimental and development work, and also the design of proper equipment to adapt the method to actual practice. For reduction to practice, a gas cleaning plant was built to handle from 3000 to 3500 cubic feet of raw gas per minute, measured at 60° F. and 30″ Bar.

The installation consisted of a primary and a secondary unit, three feet in diameter each, built separately to facilitate shipment and installation. The function of the primary unit was to humidify the gas and remove the larger particles, and that of the secondary to cool the gas and eliminate fine dust and fume and entrained water. A settling tank was provided to receive the discharge water from the humidifier and to effect partial clarification before the water was returned to the scrubber for further use. Sufficient make-up water was added to the tank from the discharge from the secondary cleaner, but otherwise the cooling water and humidifying water were kept separate.

The primary stage of the scrubber consisted of a cylindrical shell, through the center of which a vertical shaft was installed, the latter carrying four rotary water sprayers. These sprayers were made by shrinking a perforated rim onto a steel disc which carried a hub for fastening to the shaft. Water was supplied from the settling tank to the top sprayer and was thrown off tangentially in a dense spray, striking against the shell and flowing down into a roundabout trough, from which it was conveyed into the sprayer beneath, recirculation occurring as described later. In the midst of the two topmost spray zones wire screens were placed to serve as impingement surfaces and they removed considerable dust that would have escaped the densest rotary spray. A distinctive feature of the scrubber is the

means for effecting recirculation of water in each spray zone.

In creating a spray by means of a rotating element, sufficient rim speed must be employed to assure that the spray has a satisfactory density. Such a spray has considerable momentum at the end of its trajectory, or as it strikes the scrubber shell. By placing a series of properly inclined vanes on the shell to direct the water upward, any desired quantity of the sprayed liquid can be returned to the sprayer from which it was thrown, through troughs extending from the shell to the sprayer.

This method of recirculation is revolutionary in itself and offers signal advantages not found in commercial apparatus now on the market. Spray density, is, of course, independent of the volume of water entering the scrubber. The gas passage remains unobstructed, which materially reduces the pressure loss and enables larger volumes of gas to be treated in a given shell diameter. The simplest type of water sprayer is employed and repumping of the sprayed water by the spraying element is eliminated as it returns to the sprayer due to its own momentum, thus saving the power otherwise required for pumping. Such construction affords the simplest design of a scrubber employing sprays created by rotary means with recirculation of water within the scrubber itself.

The secondary stage of the scrubber was a simple plate condenser, composed of a shell three feet in diameter, and a series of perforated plates placed one above the other. The gas entered at the bottom. Cold water was supplied to the top plate at the center, flowed across the plate radially, and was conducted downward to the center of the lower plate, and so on, counter current to the flow of the gas, which was upward.

Above each plate, but close to it, was placed a grid made up of steel strips placed on edge and running parallel with the rows of perforations in the plate, which were arranged in a staggered position. The bottom edges of these strips were cut and formed so that projections, extending horizontally from each side, presented an individual baffle above each perforation. Thus a positive impingement surface was provided for each stream of gas, yet a maximum open area was left around the baffles to permit free escapement of gas after impact. Water circulated freely around the baffles to cool the gas and carry away the minute particles encountered and removed in the condensing stages.

In operation, the hot, dirty gas enters the primary stage at the bottom and flows upward in a spiral motion through two unrestricted spray zones, then through the two upper spray zones in the midst of which the wire screens are placed, then upward into the secondary stages.

Hot water flowing from the primary discharge to the settling tank or clarifier is returned to the top sprayer in the primary stage, thus completing its cycle.

In the secondary unit condensation begins as the hot, saturated gas passes through the perforations in the lower plate and encounters the cooling water. The gas passes through the water overlying the plate, and some of the wetted particles are given up, but the impact of the gas on the water's surface is inadequate for complete removal of all the wetted particles of dust and fume. Therefore the positive impingement surfaces, as previously described, are employed. These surfaces serve likewise to destroy jet action, and aid materially in reducing water entrainment. After leaving the lower condenser plate, the gas passes to the next above and so on until it leaves the apparatus in the desired condition of cleanliness and dryness.

A gradation in the size of particles remaining in the gas after primary stripping exists to a certain degree, although the range of sizes of the residual particles has been greatly reduced. The ratio of the diameters of particles in gas entering the primary may be considered as 300 to 1, the maximum size being represented by particles passing through a 100 mesh screen, equivalent to 150 microns (a micron being 1/1000th of a millimeter), and the minimum size by fume particles no smaller than ½ a micron. In the stripped gas leaving the primary stage this range is perhaps less than 10 to 1. Even so, a particle having a diameter 10 times that of another has an area 100 times as great. If condensation occurs on their surfaces, the large one would receive 100 times as much liquid as the small one, considering the liquid film as being of equal thickness in each case. Thus the small particles are still under a handicap, though of lesser magnitude.

In the first stage of a natural, or uncontrolled, cooling procedure, the largest quantities of vapor condense, with the greatest drop in temperature, and in the final stages the least quantities of vapor condense with the least fall in temperature of the gas. From the standpoint of dust removal this set of conditions should be reversed in order to condense the least vapor in the first stages on the larger particles, and the most vapor in the final stages on the smallest particles.

Such control is provided by means simple for regulating the quantity of cooling water contacting the gas in the separate condensing stages, which automatically governs the extent of cooling which may take place and, accordingly, the quantity of vapor which can condense.

It is true also that even efficient stripping of the gas in the primary stages leaves some dust in the gas which may be removed by mechanical action as provided by the impingement of the gas on the individual baffles in the condenser stages. It has been found that removal of dust by mechanical means in a series of stages follows a geometrical progression of diminishing order, and that the dust content of the gas after each step approaches a limiting value for all types of commercial equipment. However, by controlling the quantity of vapor condensing in the various stages, that is, apportioning the vapor among the various classes of particles, advantage is taken of the mechanical cleaning occurring in the first stages of the condenser, and the vapor is conserved for condensation on the smaller particles in the final stages where the effectiveness of mechanical cleaning is rapidly diminishing.

By cooling and condensing vapor in stages and with proper humidification and control, every particle of dust and fume in the gas can be removed.

To compensate for fluctuations in the heat and fine dust content of raw gas, it is advantageous at times to supplement the water vapor content of the

gas, prior to final cooling, by the use of two or three pounds of exhaust steam per thousand cubic feet of gas, or its equivalent in hot water.

The efficacy of the method and apparatus described is best indicated by the results obtained during several weeks of continuous operation at the Midland Plant of the Pittsburgh Crucible Steel Company. Gas from number three furnace, which was making both basic and foundry iron during the operating period, and carrying 1.5 grains of dust per cubic foot, and upward, was cleaned to a dust content of 0.007 grain per cubic foot. The excess moisture carried by the cleaned gas was 0.56 grain per cubic foot.

The following data, which were collected during the period of operation of the gas cleaning plant, should be of interest for comparative purposes:

Volume of gas cleaned—3000-3500 cu. ft./min. (60° F. and 30″ Bar.)
Inlet gas temperature—250-300° F.
Outlet gas temperature—70-80° F.
Cooling water temperature—60-65° F.
Cooling water required—16-28 gals. per 1000 cu. ft. of gas.
Pressure loss—8-5″ water column.
Power required—1.85 HP. per 1000 cu. ft./min. (Including power to drive scrubber and power to pump water.)
Dust in raw gas—1.50 grain per cu. ft. and up.
Dust in clean gas—0.004 to 0.0087 per cu. ft.
Excess moisture in clean gas—0.56 gr. per cu. ft.
Dust in water recirculated—800 gr. per gal.

Secondary cleaning of blast furnace gas, therefore, may be effected in one cleaning unit, and of sufficient size to treat all the gas issuing from a single furnace.

Having demonstrated the effectiveness of the method of treating blast furnace gas, and the adequacy of the equipment designed for carrying it into operation, in an experimental cleaner having a capacity of about 3500 cubic feet per minute, our company is now applying the process to a machine capable of handling 60,000 cubic feet of gas per minute and upwards.

It is believed that a very great improvement has been made in the important art of cleaning blast furnace gas, and that the steel industry will be interested in further information.

I wish to express my appreciation, and also the appreciation of Peabody Engineering Corporation, to the directors and members of the Association of Iron and Steel Electrical Engineers for the privilege of presenting this paper, also to the personnel of the Pittsburgh Crucible Steel Company for their genuine co-operation in carrying on the work at the Midland Plant, and to the officials of The Lavino Furnace Company, at Lynchburg, Va., where the process was found exceptionally effective in handling gas from a furnace producing ferro manganese.

▲

Natural Gas in Steel Plants

By CARL EMMERLING
Fuel Engineer, East Ohio Gas Company, Cleveland, Ohio.

▲

Presented before Spring Conference, Combustion Engineering Division of the Association of Iron and Steel Electrical Engineers at Youngstown, O., March, 1932.

The proper selection and application of fuels is of more importance in the making and finishing of steel than in any other of the great industries of today. The wrong fuel, or even the right fuel improperly applied, will have a far reaching effect on the cost and quality of any product of the steel industry.

Fuel is the most important raw material entering the steel plant, and its selection and application should be given as careful thought as any other of the major problems involved in steel plant operation.

When selecting fuels, a number of things must be taken into consideration.

1. Availability.
2. Uniformity, as to quality.
3. Amount of preparation required.
4. Ease of handling.
5. Accuracy with which it can be burned and controlled.
6. Effect on the product.
7. Auxiliary equipment for handling and burning.
8. Effect on life of the furnaces.
9. Cost.

Cost is given the last place in the list, because in the final analysis the cost of the fuel as delivered is of the least consideration. The real cost of a fuel is not alone the price per million BTU, but that price plus the cost of delays, rejections, furnace repairs, scale losses, handling, investment in equipment, and a dozen other items.

The amount of natural gas available for use in the steel plants has increased very considerably in the last number of years, the reason for this being deeper drilling, transportation over longer distances thus making gas from previously remote and inaccessible sources available, and the conservation of supplies of natural gas due to elimination of wasteful production and utilization methods.

Communities are usually supplied with natural gas from fields which are adjacent to one another. The gas is usually produced from the same or closely related sands, and its quality is therefore very uniform. A variation of plus or minus 25 B.T.U. per cubic foot in heat value is exceptional. It is free from sulphur, tarry matter, moisture or

other condensable liquids, and except for one or two minor uses, can be used as received from the pipe lines.

A high heat value, clean, gaseous fuel, such as natural gas, is subject to more positive control than the cruder fuels. Burners remain clean, frequent adjustments are unnecessary. The gas and air for combustion are both subject to positive regulation and can be proportioned automatically. Due to their ease of regulation, burners used on heating furnaces need not be few in number as with a liquid fuel, or large, as with producer gas or powdered coal. They can be so located as to give any desired heat distribution.

The positive control of the air-gas mixtures permits the use of any desired atmosphere in the furnace.

All of the above, together have a great effect on the quality of the product. Control of furnace atmosphere controls type and amount of scale. Accurate and uniform heating controls width and gauge on rolled products. The heat treatment of such finished products as tubing, sheets, plates, and steel castings is more accurate and faster due to a proper use of natural gas.

Natural gas in most cases is available at pressures high enough to permit the use of a high pressure inspirating type burner. With this type, no auxiliary equipment is needed. For other types of burners, using gas at lower pressures, the only auxiliary equipment needed is a relatively cheap blower, delivering air at not over one pound pressure. Usually one-half that pressure is more than sufficient.

Furnace life with natural gas is longer than with other fuels, on account of the absence of the harsh cutting action present in flames from liquid fuels, the fluxing effect of coal ash on refractories, and the absence of overheated zones in the furnace. In regenerative and recuperative furnaces, the checkers and recuperator passages remain clean, and therefore at a higher state of efficiency, as no ash or soot is carried into them by the flue gases.

There have been several new developments in the method of using natural gas, the chief of these being diffusion and luminous flame combustion.

In diffusion flame combustion the gas, and air required for combustion, are mixed, not mechanically, as in the premix type burner, but by diffusion of the air molecules into the gas, and vice versa.

This is accomplished by introducing the air and gas into the furnace in separate, wide and thin, horizontal streams or layers, the air and gas streams alternating one above the other. These streams must all have the same velocity and flow in straight lines for a considerable distance. The resulting flame is long, highly luminous, and a large percentage of the heat is transferred from the flame to the product by radiation.

True diffusion combustion so far has been used mainly in forging. A diffusion burner has been developed for this work which permits a stream of raw gas to cover the material in the furnace. This blanket of raw gas envelops the work being heated at all times, and protects it completely from oxygen or other oxidizing gases. As a result, the formation of scale is reduced to a very low figure, and, in many cases, eliminated completely. I have seen specimens of steel that have been heated in a diffusion flame to forging heat and quenched in water, that still showed the original mill marks. In fact, the steel had exactly the same appearance after heating as before.

This type of gas combustion should have great possibilities in continuous heating furnaces. While fuel costs will not be reduced to any extent over well designed furnaces using premix type gas burners, scaling in the furnace should be reduced to such a point that fuel cost will be secondary.

A saving of two per cent in scale losses will offset any increased heating cost, and show a very handsome saving beside.

As an offshoot from true diffusion flame, the luminous flame burner has been developed. This burner has the same characteristics as the diffusion flame type. The air-gas velocities are not as accurately controlled, and the result is greater turbulence and consequently a somewhat shorter flame. Nevertheless, its flame possesses a high degree of luminosity, and gives a high rate of heat transfer, good control of scale, and very satisfactory fuel practice.

Luminous flame burners were recently installed in a continuous furnace which had previously been fired with producer gas. This furnace is fifteen feet wide, about forty feet long, has a side discharge, and end charging. It is over-fired entirely, and has a solid hearth. Air, heated to about 200-250° F., is available. The maximum size billet heated is 2″ x 4″ x 14 feet, and tonnages vary from 25 tons to 200 tons per turn.

The furnace was equipped with two banks of twelve luminous flame burners, using air and gas at a maximum pressure of four inches of water. The lower bank is about 4½ inches and the upper, twenty inches above the hearth. Air and gas are supplied to each bank by separate manifolds, so that each bank of burners can be controlled independently. Individual burners can be shut off. This makes a very flexible arrangement. When the furnace is being fired at a high rate of speed, it is completely filled with flame, and even at very low rates of firing, a solid sheet of flame, the full width of the furnace, is produced.

Two and a quarter million B.T.U. per ton were required when the furnace was fired with producer gas. With natural gas and luminous flame burners, the fuel per ton was reduced to 1,760,000 B.T.U. This is the average for the week showing the highest fuel cost. Heatup gas is included.

While no definite data has been obtained on scale losses, judging by the statements of the operators and men in charge of the mill, furnace scale has been reduced at least fifty per cent.

The heating is very uniform, as proven by the uniformity in width and gauge on the finished product. Surface has been very satisfactory. All in all, it has been one of the most successful installations of natural gas in a furnace designed for another fuel that has ever come to my attention.

Considerable care must be taken in the use of luminous flame burners. All furnaces are not adaptable to this type of combustion of gas. More distance is necessary between the burner and the product heated, than with the non-luminous or premix type of combustion. Turbulence must be kept at a

minimum to prevent undue shortening of the flame. This is sometimes not possible with existing furnaces. The ideal situation would, of course, be to build furnaces designed for this type of combustion.

Luminous flame combustion is being used by several of the steel plants in the districts served by our Company with satisfactory results, both as to fuel practice and quality of product.

In one installation, consisting of three continuous heating furnaces, a fuel saving of fifteen per cent was effected by replacing premix with luminous flame burners. The quality of product was improved due to the formation of a type of scale more easily cleaned from the steel.

The use of luminous flame combustion has been found useful in sheet and pair heating. Fuel cost and quality were both improved by its use.

I believe that both true diffusion and luminous flame combustion of natural gas have a great future, particularly in steel plant heating, and their possibilities are by no means fully developed.

One of the companies that was instrumental in developing this diffusion flame burner believes that diffusion combustion has a very decided advantage in open hearth heating, and I am in hopes that some day a setup can be worked out whereby this can be tried.

Natural gas has by no means reached the end of its possibilities in steel mill heating. There are a number of heating processes that are still quite crude and undeveloped.

For instance, in box annealing of sheet steel and strip. In most steel plants, this particular heating operation has not been improved to any extent in quite a number of years. In many plants, hand-fired coal, powdered coal, and producer gas are used. With the advent of full finished, normalized auto body sheets and strip, this annealing operation has become very exacting. The temperature limits between which the operator must work are very narrow and not much below the furnace temperature.

As a rule, the furnaces are fired from one side, as they are built in pairs with a common side wall. This method of heating requires a flame which is very long and slow burning. The air for combustion is usually obtained by means of a chimney draft, and in order to obtain the required uniformity, an insufficient amount of air is used which results in poor combustion and high fuel cost.

Some experiments in progress at the present time indicate that not more than one and one-half million B.T.U. are required for the most exacting of this annealing, and the time in the furnace can be reduced at least twenty-five per cent.

If the heavy cast iron covers and trays commonly used are replaced with light alloy or even plain carbon steel covers and trays, this time and fuel cost should be reduced even more. One million B.T.U. per ton is not impossible.

The importance of this annealing is best proven by the fact that some of the makers of very high grade sheet and strip, in their attempts to solve the annealing problem, are using electric furnaces for this work. About 200 KW., or 680,000 B.T.U., are required per ton. In furnaces properly designed and using the same type of alloy cover and tray as are used in electric furnaces, 1,000,000 B.T.U. in the form of natural gas will do the job, and if the weights are kept as low as in electric furnaces, the annealing time should be the same.

Under these conditions, the comparison is obvious. The heating can be done for less than one-half the cost, if natural gas is used.

Of course, this cannot be obtained by installing a gas burner in any old furnace; the furnace must be designed for the work and fuel.

I have been requested to describe some tests that our Company helped conduct on atomizing fuel oil with compressed natural gas in open hearth furnaces.

The theory behind these experiments was this. Natural gas under pressure is dissolved in petroleum oil in a manner similar to the solution of carbon dioxide in water. When the pressure is released, considerable effervescence occurs. It was thought that for this reason, when a mixture of fuel oil and natural gas were released from under pressure at the burner nozzle, the oil would be more finely divided than with steam atomization, and more surface would be exposed to the air from the checkers, resulting in faster combustion, with higher temperatures and a sharper flame, and that this would result in faster melting down of the scrap and pig.

The special apparatus used for the test consisted essentially of a reciprocating compressor capable of compressing gas to 150 pounds per square inch, together with the necessary regulating devices required to maintain constant gas pressures under the conditions that exist in open hearth firing.

The test was started using the oil burner in exactly the same way as with steam atomization. Natural gas at 150 pounds was merely substituted for the steam. As the test progressed, a number of slight modifications were made in the burner, mainly in the length and diameter of the injecting tube through which the gas entered the burner.

When several difficulties had been ironed out, very satisfactory results were obtained. Time of heats was reduced and fuel practice was improved, and the practice was made standard at the plant where the experiments were made.

The same setup was then installed in a second plant where carbon steel instead of alloy steel was the usual product, and tar was used as fuel instead of oil. In this plant for some reason it was impossible to duplicate the results obtained in the first, and after a very fair and entirely impartial test, lasting about three hundred heats, it was found that no particular advantage resulted from the use of natural gas and tar, over steam and tar, and the work was discontinued.

A satisfactory explanation of why the tar and gas in furnaces making plain carbon steel did not show the same improvement as oil and gas did in a furnace making alloy steel, was never arrived at, and no further work has been done on the matter.

I believe, however, that in certain steel plants, if natural gas were available at pressures high enough to eliminate the use of a compressor, this method of firing open hearth furnaces would have sufficient advantage to make it very attractive.

Natural gas by itself, in a properly designed open hearth, is a fuel that leaves little to be desired. Fuel handling is reduced to its simplest form. Furnace repair costs are reduced by as much as fifteen cents per ton. Unfortunately, with the present very low oil prices, there are very few gas companies that can

afford to sell natural gas at prices that would equal the fuel costs obtained with fuel oil. However, new developments, particularly diffusion flame combustion, may alter the picture materially.

In closing, I wish to say a word of warning. Natural gas is not a cure-all for every heating trouble. Without a doubt, it is the ideal fuel for steel plants, and when used in properly designed furnaces, will give results that cannot be equalled with other fuels. In order to obtain these results, careful study of the conditions surrounding the operation are necessary, and a burner application and furnace design must be used that will bring out the advantages of natural gas.

The day of a piece of pipe for a burner and any old furnace is past.

▲

The "Combination System"

▲

By R. J. WEAN, President
Wean Engineering Company, Warren, Ohio.

Presented before Spring Conference, Combustion Engineering Division of the Association of Iron and Steel Electrical Engineers at Youngstown, O., March, 1932.

The "Combination System" is not only a method of making sheet and tin plate but it is also trade marked. In describing the "Combination System" —why and how it was developed—it seems desirable to commence at 1900 and review the history of the various methods and equipment used in the sheet and tin plate industry. It should also be pointed out that in discussing this subject it is not my desire to adversely criticize any other method of making flat rolled steel, but rather to establish for the industry and those connected with it the fact that conventional or old style sheet and tin mills properly modernized can compete with any other form of flat rolling and in some instances will have quite an advantage.

Throughout the sheet and tin plate industry from 1900 until within the last few years there was an extreme lack of equipment development for the hot mill division. In-and-out furnaces where the material was handled into the furnace by the men manually, removed in like manner and conveyed to the mill either by some form of conveyor, skids or mono-rail system, or perhaps dragged on the mill standing, were used quite generally. Hand rolling methods were employed entirely and all of you are no doubt familiar to some degree with this practice. The number of heatings required from bar to the finished gauge depended entirely on the thickness and size being rolled—rarely less than 2 and seldom more than 4.

The manual labor involved in heating and rolling was quite arduous, required a high degree of skill and resulted in very low tonnage productions.

While in general the practice throughout these years remained the same, a thorough study of operating records reveals that as early as 1902 what is known as the "Double Mill System", consisting of roughing on one mill and finishing on another, was used and it is found that as early as 1900 the leading sheet and tin plate interest was conducting hot mill operations whereby the runover pass was eliminated in one of their sheet mills and this was called the "Three Part System", the name being derived from the fact that only three heatings were required as compared to four previously.

An interesting side light on this is that as late as 1925 the claim of an inventor was that the elimination of the run-over pass was new even though it was common practice 22 years before he filed his patent application. It is also interesting to note that even though for a great many years the sheet and tin plate industry worked along with the in-and-out type of furnace requiring numerous heaters and heater's helpers, there was a patent taken out in 1903 on a continuous heating furnace where the material was conveyed through the furnace and delivered to the mill without coming in contact with the mill floor, worked back and forth and returned on a conveyor above the mill floor to the charging end of furnace for additional heating and subsequent rolling.

An interesting item of this patent record is the recommendation by the inventor that the furnace be 50 feet long which is about the length continuous furnaces were built a year and a half ago. It is quite evident that the inventor was many years ahead of the industry.

The first real effort made to improve sheet or tin plate rolling methods was the construction at Farrell, Pa., about 1904 of what is known as the "Bray Mill". This mill was set up as a continuous method of producing light gauge sheets or tin plate. Failure of this mill to perform satisfactorily can be traced directly to the inadequate power and mechanical facilities available at that time. I believe I would be entirely safe in saying that with the electrical equipment and machinery available today, a modification of the Bray Mill could be operated successfully.

Through all the succeeding years up until the more recent developments, there were sporadic efforts to develop mechanical handling units to apply to sheet and tin mills, some of which expected gravity to perform miraculous results, others depending upon the material becoming animated in order to function. Stunts and freak ideas were the order of the day rather than sound engineering.

For a period of years from 1915 to 1923 or 1924 the only seeming improvement on hot sheet and tin mills was that furnaces were becoming wider and that tonnages were increasing somewhat as a result of heavier mills, and the development in the manufacture of rolls.

About 1924 the American Rolling Mill Company, after many years of study, decided to build what is

now their Ashland plant. This mill was built to make sheets continuously and was successful. In fact, I incline to the opinion that this mill today can make 19 and 20 gauge full finished sheets cheaper than a combination of continuous hot and cold roll strip mills. This mill has been described numerous times in trade journals and papers before other Societies and is mentioned as "only a stage in the development of flat rolling".

At about this time a continuous hot strip mill was built at Butler, Pa., to make what is known as sheet strip, and was a decided contribution to the art of flat rolling steel. Prior to the completion of the mill, reckless statements were made as to the saving that would result in the manufacture of full finished strip to meet automobile requirements, and it was at this time that sheet prices started to become demoralized.

A short time later a strip mill to make 36" wide, hot rolled material was installed at Gary to roll to 16 gauge in thickness, the material to be used for tin mill breakdown, this strip being cut up, doubled cold into packs of four, heated and subsequently finished on conventional tin mills.

The starting up of the Butler and Gary plants marked the invasion of the strip mill into sheet steel sizes and many of the old style sheet mill owners and operators stated to me that the old style mills were doomed. An intensive study of both styles of mills—strip and conventional—made possible through the co-operation of steel company executives, brought me to the conclusion that the costs claimed on wide strip mills were based more on hope than fact and that the future of both strip and sheet producers could best be served by working together, and so stated at a meeting of the American Society of Mechanical Engineers, Iron and Steel Division, in this room in 1927.

The plan in connection with the Butler strip mill was to cold roll the hot strip and process it to meet the automotive requirements, while at the Gary mill the subject was approached in a much more rational manner and, as has been proven, with a great deal of foresight. Instead of attempting the complete reduction in the form of strip as has been previously mentioned, the intent was to make strip breakdown. Executives in charge of the work saw clearly that if a continuous furnace could be developed in front of the conventional tin mill on which the material was to be finished, quite a saving could be made at this point. A furnace installation was made by one of the commercial furnace companies but the heating results were far from satisfactory. The engineers of the Steel Company and some outside consultants studied the problem of developing a furnace that would give satisfactory heating results and after considerable expenditure of money and effort what is known as the "Radiant Gap" furnace was developed—there are today about 130 of these furnaces either in operation or under construction.

At the same time, the old problem of trying to handle mechanically the material on the mill was attacked. Numerous designs of mechanical catchers were developed and the late Arthur R. McArthur played a prominent part in these developments; however, the particular designs evolved did not measure up to the requirements, and again the future of the old style sheet and tin mill did not seem very hopeful.

The development of the wide strip mill was a serious problem for the sheet and tin plate industry to face when it is realized that the sheet industry alone represents an approximate investment of $175,000,000 and has under normal conditions employed upwards of 50,000 workmen and that the tin plate industry would more than double this. In some districts entire communities are dependent upon the sheet or tin mills as a source of employment, and the elimination of the old style sheet and tin mills might make it necessary to support these communities by charity; it was also quite possible that these communities would eventually be abandoned, causing municipal and civic disorder.

These factors were all given due consideration by the executives of the leading sheet and tin plate interest. They felt that the problem of mechanically handling the material on a sheet or tin mill had not been exhausted and they assigned their best engineering talent to its solution. It was also with these thoughts in mind that the "Combination System" was developed and brought to the attention of the industry.

A very fine scientific approach to the problem and intensive efforts in research work resulted in the development of automatic feeding and catching tables that would perform as fast as the mill could roll the material. During the period of development, the motor and control specifications set up were said by the electrical equipment manufacturers to be impossible to meet. Refusing to accept this answer resulted in the development of electrical apparatus to permit this equipment to function constantly and efficiently.

While these tables are only a part of the "Combination System", we do not want to pass over this in a too casual manner as ten or fifteen years from now the development of these—the first automatic feeding and catching tables that would absolutely perform in a satisfactory manner in regular operations—will be recognized as a major contribution in the field of invention and should bring a great deal of fame and recognition to the inventors as well as benefit to the steel industry.

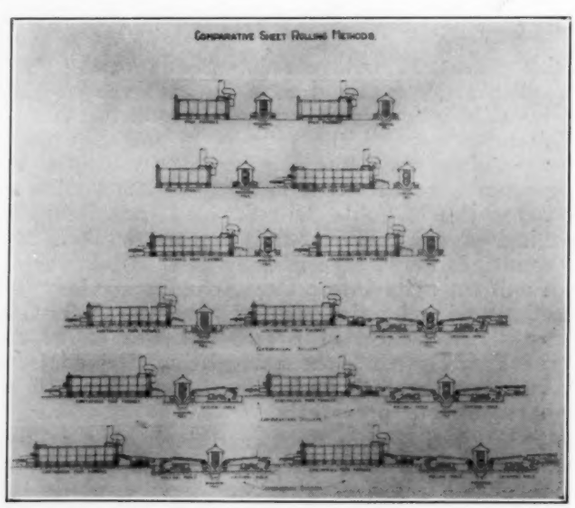


FIG. 1

In its essentials the modern rolling and catching tables have a cantilever frame trunnioning at the end farthest from the mill rolls. The top surface of this cantilever frame is arranged to accommodate a conveyor upon which the material being rolled is conveyed to and from and through the mill within the confines of suitable guides.

Power for both tilting and conveying is provided by special A.C. motors. The tilt motor operates intermittently in one direction; the conveyor motor which is reversing, operates almost continuously. For actuating the motors in correct relation, an ingenious electrical control has been developed. This control is operated through a flag switch by the material in process and makes possible either automatic or manual performance at the option of the workman.

During the period this equipment was under development, a large number of continuous furnace installations had been made throughout the industry. In spite of the known fact that mechanical equipment was under development and that any furnace installation should have the ability to discharge the material, many installations were made where it was necessary to withdraw the material manually and the usefulness of this type of furnace today is not much greater than the very old style of in-and-out furnace.

Coming into the year 1930, it was plainly seen that if all the various developments could be correlated and coordinated, and the sheet and tin plate industry would be willing to adopt a new system, there was a real opportunity to increase production and decrease cost.

With this in mind, a chart as shown in Fig. 1 was made up depicting the various progressive stages in sheet rolling. In addition to this, an elaborate study and chart of the manner in which the various sizes and grades of product could be made was prepared, breaking up the operations so that the proper division of roughing and finishing would exist. Executives having many years of experience in the sheet and tin plate industry went over the charts and studies and stated that to use the equipment proposed and methods outlined would mean a new system of sheet rolling and in order to have it referred to uniformly it was decided to name it the "Combination System". A patent application was filed and the name was adopted as a trade mark.

The first sheet mill installation in an independent mill was at the Superior Sheet Steel plant of the Continental Steel Corporation at Canton, O., early in 1931; and the first tin mill installation in an independent plant was at the Trumbull mill of the Republic Steel Corporation about the middle of 1931. These were the first two "Combination System" installations for sheet and tin products made in independent mills, although there were numerous earlier installations in the various plants of the company where the equipment was developed.

During the year some 26 mechanical units were installed and by this time the total number of continuous furnaces throughout the industry had reached about 200.

This "Combination System" has permitted a reduction in cost and an increase in production far in excess of that expected. Naturally, during the year as the equipment was operated, further experiments were carried on by the inventors and developers which disclosed that certain improvements were desirable. As an example, it was found it was absolutely necessary (as had been anticipated a long time before) that furnaces when built in double width sizes should have both lines of conveying

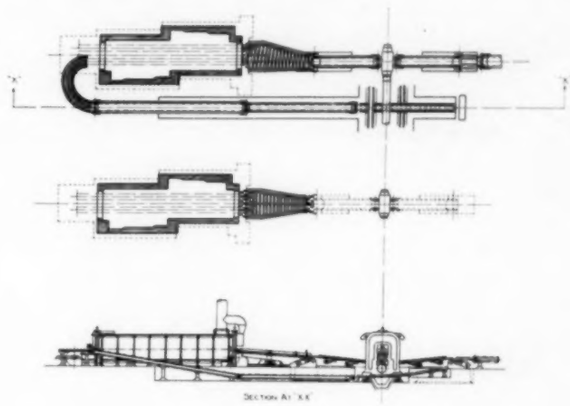


FIG. 2

apparatus independently operative and dischargeable at will. No fixed time cycle is permissible at this point without a delay in production as frequently one pack from each conveyor must follow the other one within two or three feet, and where a fixed time cycle or operation is built into the equipment, this is impossible.

Another need that evidenced itself was power driven runout conveyors between the furnace and the feeding table to replace gravity units as originally installed on many furnaces. This was met by the development of what is known as the skew table which is placed in front of the furnace so that one line of the furnace conveying apparatus is directly in line with the mill, and the material from the other line of the conveyor which is offset from the mill is delivered on an angle from the skew rollers so that it will enter the feeding table correctly. This can be seen in Fig. 2.

Another improvement found desirable was to have the feeding and catching tables designed so that the tilt point would be at the extreme end of the tables instead of approximately midway. This was done to obtain the proper means for delivering the sheets substantially flat-wise from the catcher to the feeder and to eliminate shifting of material on certain grades of product. Naturally, in moving this tilt point to this position the angle of the mill was much more flat than on the old style tables.

In addition to this, the driving means of the equipment having been on the side of the original tables, was found to interfere in many cases with existing doubler installations and made it necessary to have the equipment right and left hand to conform to the requirements.

Experiments and tests resulted in what is now known as the Model "B" table, which has supplanted Model "A", and Figure 3 clearly shows how this table—being symmetrical about the center line of the mill—permits the operator to work on either side and eliminates all danger of interference with other auxiliary equipment. The tilt point of

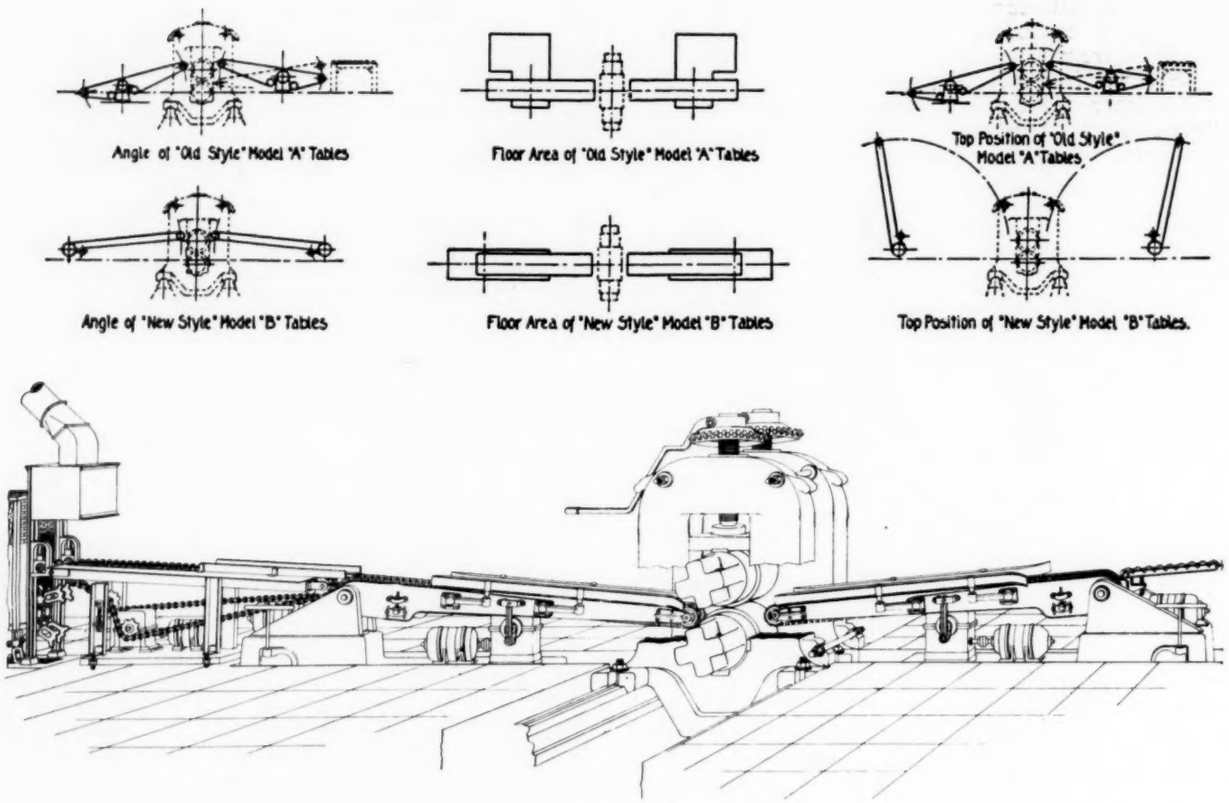

Angle of "Old Style" Model "A" Tables
Floor Area of "Old Style" Model "A" Tables
Top Position of "Old Style" Model "A" Tables.
Angle of "New Style" Model "B" Tables
Floor Area of "New Style" Model "B" Tables
Top Position of "New Style" Model "B" Tables.

FIG. 3

the table being at the end provides for the proper angle of delivery over the rolls as well as contributing to much improved operating conditions. It also made it possible to place the table in an upright position for mill changes by either power or crane without a deep pit in the foundations.

Inasmuch as return conveyors were necessary to eliminate material handling and in order to have the mill entirely accessible as well as improve the general appearance, these return conveyors have been placed in a plane below the floor level as noted in Figure 2. The material returns under the mill spindle and remains under the mill floor entirely, arriving at a point behind the front of the furnace and then elevates gradually to the charging platform height at the charging end of the furnace.

With installations of this kind, extremely high tonnages have been produced of both light and heavy gauge, and with the equipment assembled in this manner coordination of all the units has been so successfully accomplished that split seconds are now counted and studied for further elimination of lost time, and it is quite easy to determine the tonnage that can be procured from a mill if given the size of material and number of passes required.

Using 27 gauge 120 long, 29 wide as an example, the production on an old style mill was about 10 tons in 8 hours, whereas on the "Combination System" unit it has been as high as 41 tons, with an average of 30 tons in 8 hours. The total labor cost would be about $5.00 per ton less on the new "System", and the men operating the equipment earn about as much in 8 hours as before but must produce the greater tonnage in order to do so.

A sheet or tin plate producer wishing to use the "Combination System" and desiring the lowest ultimate production cost—which I believe is the aim of all producers—should approach the problem first by determining the cheapest fuel available. Furnace installations should not be made on a basis whereby they are limited to the use of one fuel. As an illustration, while today oil in this district can be secured at a price that will permit sheet heating cost to equal about one-half of that when using natural gas, this may not always hold true, and therefore the producer should provide himself with equipment that will permit him to use either fuel depending upon which is the cheaper available at any time. Or, he might even go further and provide in the equipment for the possibility of using producer gas if the other two fuels become prohibitive in cost.

It seems almost absurd to hear operators trying to reduce their fuel cost 5 or 10% and at the same time using the most expensive fuel available in this district. Certainly, such a practice cannot contribute to lowest ultimate cost.

The producer must further satisfy himself that the equipment he installs will absolutely permit coordination of all units and have no fixed limitations of production other than the speed of the mill.

The operation of the mechanical equipment of the "Combination System" is entirely automatic so that any lost time or lost production can generally be attributed to the operators or mill conditions. When equipment is installed that will not coordinate

properly, there is a resulting loss in production of 20 to 30%.

The "Combination System" in reality employs a roughing mill equipped with a continuous furnace, operating in connection with a finishing mill equipped with a continuous furnace and automatic feeding and catching tables, including the essential conveying and other auxiliary apparatus. The benefits to be derived from the "Combination System" are:

Greater production per mill stand.
Better quality of product.
Elimination of manual and skilled labor.
Higher percentage of prime material.
An eventual lower scrap loss.
Lowest ultimate cost.

We believe the statement is quite safe that today sheets 20 gauge and lighter—and possibly some heavier—can be made by this "System" at a cost comparable with wide strip mills and in many instances lower when the proper equipment is used in connection with the "Combination System".

All of the sheet and tin mill apparatus involved in the "Combination System" is covered by either letters patent or patents pending and the Wean Engineering Company either owns or is licensed under such patents and patents pending.

▲

The Combination Method

By H. MELIN
Engineer, Aetna-Standard Engineering Co., Youngstown, Ohio.

▲

Presented before Spring Conference, Combustion Engineering Division of the Association of Iron and Steel Electrical Engineers at Youngstown, O., March, 1932.

The Combination Method is a means of producing sheets in the most economical manner and does not represent a radical departure from present methods, but constitutes rather an assembly of those facilities that are now proven and in use.

In the Combination Method, use is made of a continuous furnace, a sheet mill, suitable conveyor from furnace to mill, mechanical means of handling the metal during rolling, suitable return conveyors from mill to furnace, an automatic doubler and such other appurtenances as automatic top and bottom roll polishers and the like.

The necessity for the development of this Method was largely brought about by the introduction of the continuous wide strip mill plus the fact that operators of conventional sheet mills have realized that by its adaptation to their present equipment they have an opportunity to regain their prestige.

To fully perceive the advantages obtained by this Method, a brief outline of the hot rolling process in the so-called conventional sheet mill may be called to attention.

In design and practice, the conventional sheet mill is today practically the same as when first introduced in this country several decades ago. Of course, there have been numerous improvements made from time to time to enable the equipment to meet the ever-incrasing demands for greater tonnages and higher qualities but the rolling method as a whole has not deviated to any great extent from the original. A sheet rolling unit consists of a pair furnace, sheet furnace, one 2-high hot mill for roughing and finishing, one 2-high wet mill for breaking down heavier bars, and a doubler. A number of mill stands are placed laterally at proper distances on continuous mill shoes. All lower rolls are connected by spindles and rigid coupling boxes and driven from a centrally located drive. The furnaces are located in front of the respective mills approximately 30'0" from the center line of the rolls, and the doubler between the furnace and the mill. Each sheet rolling unit requires a crew of nine men; namely, a roller, roller's helper, heater, heater's helper, rougher, catcher, pair heater, matcher and doubler, or extra man.

Sheets are rolled from sheet bar, which is heated in the pair furnace, conveyed in pairs to the mill stand, rolled in single and matched passes to breakdown gauge, returned after matching to the sheet furnace, reheated, conveyed to the mill and rolled in one or several passes either to finished gauge or doubled for further reheating and rerolling into lighter gauges. During this process the bars and packs have been charged and discharged manually into the pair and sheet furnaces. They have been dragged on the mill floor from the furnace to the mill. They have been entered into the mill, caught on the opposite side of the mill and returned over the rolls for additional passes manually, and have been dragged back and forth from the mill and to the sheet furnace, charged and discharged also manually.

The handicap of the absence of all mechanical appliances for handling the material during the heating and rolling process naturally has limited the production of a sheet rolling unit to the physical capacity of the man power available. Due to the working conditions, the gruelling efforts necessary and the high type of skilled labor required, the labor cost for producing sheets by this system is necessarily high. The tonnage produced on a mill operated as described above varies naturally with the gauges and sizes rolled. With an average gauge of 26, a fair production per 8-hour turn will be 9 tons.

The conventional sheet mill experienced a very decided competition with the advent of the continuous wide strip mill. In a wide strip mill, slabs are hot rolled continuously into strips as light as 16 gauge. By a series of cold rolling processes, the hot rolled product can be further reduced to the lightest gauge required of the sheet and tin mill industry. The continuous strip mill is designed for the greatest efficiency and equipped with the most up-to-date labor-saving machinery whereby the man hours per ton produced have been reduced to a

negligible minimum. One continuous mill can produce a tonnage equal to the capacity of 60 stands in the conventional type mill. Fears were immediately broadcast that the old-fashioned sheet mill had outlived its usefulness, over-shadowed by this new competitor. The disadvantage of the continuous wide strip mill is its high initial cost of installation, which necessitates a heavy fixed charge, which is counter-balanced by economies effected in rolling a normal tonnage, but becomes very noticeable if rolling schedules are light. Another decided disadvantage is that the continuous wide strip mill has not the flexibility required for small tonnages of varied specifications, which is indeed a handicap, especially in sub-normal times.

The Combination Method has eliminated, with very little additional expense, the disadvantages of the conventional sheet mill as compared to the continous wide strip mill, but has maintained all the advantages of the conventional mill over the continous mill.

The Combination Method, as stated, consists of a continuous furnace, a sheet mill, suitable conveyor from furnace to mill, mechanical means of handling the metal during rolling, suitable return conveyors from mill to furnace, an automatic doubler and automatic top and bottom roll polishers.

The continuous furnace that has been developed for heating pairs and packs within the past few years contributes in a very great degree to the success of the entire method. To produce sheets of high quality without excessive loss in scrap, it is essential to have uniformly heated packs of the correct temperature. This the continuous pack furnace of today will do. Several types of these furnaces are on the market. Those most commonly in use are the chain type and the walking beam type. Due to the limited furnace space available in existing mills, the double width furnace has been almost universally adopted. In these furnaces two rows of packs are heated simultaneously. The furnace is located on the center line of the mill at right angles to the mill train. Early installations of continuous double width furnaces used in the old-fashioned sheet mill had a length of from 30′0″ to 35′0″. Today, double width furnaces are built 55′0″ long with a heating capacity of 20,000 lbs. per hour; and when used in the Combination Method, this capacity has not been found excessive. As these furnaces will be described in papers to be read later today, it is not here necessary to go into details as to design and performance.

Between the discharge end of the furnace and the automatic feeder, a gravity or power driven conveyor is installed. This conveys the pack from either row in the furnace squarely into the feeder.

The Automatic Feeders and Catchers in present installations vary in design considerably.

The Feeder and Catcher designed and built by our company consists of two tilting tables, each about 13′0″ long, placed on opposite sides of the sheet mill. The tables are pivoted on the end furthest from the mill. Each table is equipped with power driven endless chains to feed the packs into and over the mill. These chains are fully supported over their entire length to prevent undue wear and provide smoother operation. Insulated blocks are attached to both sides of the chains, projecting above the chain proper. Due to the low conductivity of these blocks, very little of the heat in the pack is lost by contact. The blocks also provide a greater supporting area for the pack, as well as increased friction, preventing excessive run-backs in reversing. The chains are driven by a specially designed motor through two gear reducing sets. The tilting action of the table is attained by a crank motion actuated by a specially designed motor driving through a gear reduction. The motors and controls for these tables will be explained in detail in a paper later today.

Both the feeding and catching tables raise and lower simultaneously. During the rolling process the side guides are automatically opened on the feeding table in the elevated position and closed in the lowered position. On the catching table the guides are opened in the lowered position and closed in the elevated position. This keeps the pack square as it enters the mill and also delivers the pack over the roll from the catching table in exactly the same line. This is a decided advantage in rolling loose packs to prevent spreading. The guides can be adjusted for various widths by hand. The chains are driven at a speed approximately the same as the lineal speed of the rolls, and chain travel is reversed as the tables are elevated or lowered automatically. The tables are tilted at a speed approximately as fast as the pack will fall by gravity, and are manipulated from one central master switch located close to the mill.

The entire feeder and catcher is a compact unit which can be installed or removed very readily and requires only a 10″ depression in front and back of the mill. The motors are not located directly underneath the table, but slightly to the side.

In this Method, an automatic top and bottom roll polisher is essential for conditioning the surface of the rolls. The rolling is continuous and any time required for polishing by hand would be directly responsible for decreased production.

The Aetna-Standard Automatic Top and Bottom Roll Polisher is designed to be attached to the roll housing of any standard sheet or tin plate mill. It can be attached to the mill housing in a few minutes without the aid of tools of any kind other than a small wrench and a hand hammer. This operation can be performed with the rolls in motion.

During the polishing action the stones travel back and forth over the entire face of the roll. This travel is governed by stops mounted on the bottom polisher housing. The stones may be stopped in any position for localized polishing or the direction of travel may be reversed at will. The polishing action is adjustable to any width of roll. Pressure of the stones on the rolls is applied by springs, which may be adjusted to suit prevailing conditions and the angular contact of the bottom stone with the roll face is controlled by a wing nut and screw.

Motive power is taken from the wabbler end of the top roll and transmitted through a connecting rod to a ratchet wheel mounted on the driving screw of the bottom polisher. The top polisher screw is driven by sprockets and a chain from the bottom screw.

Due to the close proximity of the top polisher supports to the mill rolls, the top driving screw has been made hollow for the circulation of cooling water.

In event of a broken roll, the breaking of a small pin in the bottom polisher arm allows this arm to drop away from the roll, thus eliminating damage to the stone or support.

The operation of the Combination Unit is as follows: The breakdowns are charged manually into the furnace and heated. When the roller is ready for a pack, he presses a push button conveniently located, which opens the discharge door of the furnace, discharges a pack and immediately closes the door. As a pack is fed from the furnace, the operator pulls back on a single control lever which opens the side guards and raises the stop at the front of the feeder table. He also pulls the lever to the right which starts the chain motors and the pack is carried down against the stop, which end matches the pack. The lever is then released and it returns to neutral position, which stops the chains and closes the side guards, which side matches the pack and squares it up with the mill. If only a single pass is to be made on the pack, the handle of the lever is thrown directly to the right which starts the chain motors and feeds the pack into the mill and runs it out onto the catcher table and onto a discharge conveyor. However, if several passes are to be made on the pack, the operator throws the control lever straight forward into the automatic position, which also starts the pack through the mill but puts the equipment into automatic operation actuated by the trigger switches on the table. Therefore, as the pack passes onto the catcher table, the tables raise and the chains reverse, bringing the pack back to the feeder's side of the mill. This cycle of operation is repeated continuously as long as the control lever is left in the automatic position.

When the operator desires to stop the pack, he pulls the control lever out of the automatic position into neutral, and the pack is automatically brought back to the feeder table.

When rolled to the desired gauge, the pack is run off the catching table and delivered either to the doubler or to the shears. The packs are manually opened and doubled. The automatic doubler is installed in the rear of the mill, which is decidedly the most advantageous location.

The doubled packs are placed on a gravity conveyor which delivers the packs to a chain conveyor which, in turn, delivers the doubled packs to the charging end of the continuous furnace, where they are manually charged for reheating. The entire heating and rolling process is accomplished with one charger at the heating furnace, one roller, one roller's helper, one opener and a doubler—a total crew of five men.

During the entire rolling process the pack has not been handled manually from the charging end of the furnace until rolled into doubling or finished gauge. The physical effort of the crew has been minimized to a great extent and only two men of the crew must have skill above that of the ordinary laborer. The tonnage produced on a unit of this type varies with the gauge; but judging from results obtained from present installations, it is fair to assume a production of 25 tons per 8-hour turn. The wage scales for hot mill rolling in the conventional sheet mill cannot, of course, be applied to a unit of this kind, due to the greatly increased production, as well as the improved working conditions and the type of labor employed. It is, therefore, possible to produce by the Combination Method finished sheets from breakdowns at a hot rolling labor cost of approximately $1.30 per ton.

The Combination Method does not as yet include any provision for producing required breakdowns.

Breakdowns can be rolled from bars on the conventional 2-high sheet mill equipped with a continuous pair heating furnace. A unit of this kind with a crew of six to seven men will produce an average of 20 tons of breakdowns per turn at a labor cost of approximately $1.50 per ton. Finished hot rolled sheets, unsheared, can thus be produced by the Combination Method with the conventional sheet mill as producer of breakdowns, for a total hot rolling labor cost of approximately $2.80 per ton. This compares with an average hot rolling labor cost of from $7.00 to $8.00 per ton when rolled on the conventional sheet mill—a saving of approximately $4.00 to $5.00 per ton in favor of the Combination Method.

If the breakdowns are produced from sheet bar on a 3-high mill equipped with mechanical feeding tables and continuous heating furnace, the savings effected will be still greater. The tonnage of a mill of this type is about 40 tons per 8-hour turn with a crew of six men.

Our company has further developments of the Combination Method under way which will be announced very shortly.

▲

Continuous Heating Furnaces

By H. P. McCANN,
McCann Engineering Corp.,
Cleveland, Ohio

Presented by R. L. CORBETT,
Vice President, McCann Engineering Corp.,
Pittsburgh, Pa.

▲

Presented before Spring Conference, Combustion Engineering Division of the Association of Iron and Steel Electrical Engineers at Youngstown, O., March, 1932.

I have been asked to read a paper today dealing with the subject of Continuous Heating Furnaces. Now, this is a rather broad and lengthy subject should I attempt to cover the entire field of Continuous Furnaces or even to limit myself to those furnaces best adapted to general steel mill practice. From a review of the papers to be read here today I judge that what you are most interested in is the Continuous Furnace as adapted to the sheet and tin industry and I will, therefore, endeavor to confine my remarks to the several characteristics, adaptability and limitations of the several types of furnaces now in general use for Pack and Pair heating

and for sheet, strip and tin plate normalizing. I will also largely confine my discussion to the method of conveying.

There are three general types of furnaces now used for this purpose, based on the method of conveying the material through the furnace—the roller bottom type, the chain conveyor type and the walking beam type.

A great many roller bottom furnaces are in service today and up to a very few years ago was the most successful type of conveyor that had been tried out for normalizing and pack heating. Why this was so, I cannot say, since the walking beam principle has been known and used for the past thirty or forty years and has been used by myself in the automotive industry for close, accurate heating work for the past fifteen years. I guess the main reason was that most of the furnace engineers were too busy keeping up to the demand for special production equipment to realize that the steel mills also required continuous furnaces. I think also that the mills were largely to blame since up to recently they were very reluctant to adopt advice on furnace construction from the furnace manufacturers.

The shafts on rollers which form the conveyor in these furnaces are divided into three distinct classes—the watercooled shaft, the insulated shaft and the dry shaft. Quite a lot of competition and argument has surged around the proponents of each type but regardless of the fact that the dry shaft and insulated shaft have both greatly reduced the fuel consumption per ton of metal heated over the old type of watercooled shaft. This type of furnace has certain inherent disadvantages which makes it very unlikely that many more installations will be made. These disadvantages can be summarized as follows:

First, the large amount of alloy required for the shafts and discs which makes this type of furnace very expensive in first cost and in maintenance.

Second, comparatively high fuel consumption due to heat transmitted through the ends of the shafts which necessarily must extend outside the furnace walls.

Third, an excessive chamber volume made necessary by the large diameter of the discs which greatly increases radiation losses, air leakage due to difficulty in maintaining the packing and the shaft openings.

Rider or waster sheets must be used on all high grade sheets, especially on normalizing, since these alloy discs have a bad habit of picking up oxide scale which forms tits or sharp points on the face of the discs and which mark and scratch the sheets. Since these wasters must be heated the same as the prime sheets the fuel losses are considerable. To this additional fuel cost must also be added the cost of replacing the wasters, cost of handling, etc.

In order to get away from these troubles, the chain conveyor furnace has been tried out in a number of mills with varying results. This type of furnace can be divided into two general classes—the hot chain type and the buried or protected chain type.

The true hot chain conveyor should have the carrying and return strands of the chain as well as the terminals, that is, the driving and tail sprockets, all inside of the furnace. This would make a very economical and simple conveyor were it not rather difficult to operate and maintain shafts, bearings, takeups, etc., at the temperatures encountered in these furnaces. Many engineers would hesitate to recommend such a design due to the possibility of the chains breaking under load. It is very easy, however, to design an alloy chain that will have as high a factor of safety under these temperatures as ordinary chain at room temperature, despite the fact that no lubrication is possible. This is not the difficulty. The difficulty lies in the impossibility of maintaining an accurate relationship between the pitch of the chain from cold to hot and the pitch of the sprocket. This causes the chain to ride the sprocket teeth and eventually slip a tooth. This causes an uneven motion of the chain and due to the jerking sometimes causes chain failures.

Another defect of chain conveyors if operated without cross-ties between the strands and when very well guided, is that each strand will pull or weave from side to side which will cause scratching on particular work, such as on full finished sheets.

This type of chain furnace has not to my knowledge been used to any great extent.

The most common application of the hot chain is to place the sprockets outside the ends of the furnace where the bearings can be watercooled and lubricated and to return the chain under the furnace. If the drive sprocket is placed close to the discharge end the same difficulty of the chains riding the sprockets would be encountered. This type of conveyor also has the additional disadvantage of the chains carrying a large amount of heat out of the furnace. In heating packs or sheets where the material weight is approximately the same or less than the chain, the increase in fuel consumption is a very serious item.

Probably the most common type of chain conveyor is the type where an ordinary steel chain is carried on a track buried in the brick hearth of the furnace. In some cases watercooled pipes are also imbedded in the hearth to keep the track and chain cool. In other designs the track is mounted on the bottom plate and radiation and conduction is depended on for proper cooling. In either case blades, pins or other attachments are mounted on the chain at intervals and these operate through a continuous slot extending lengthwise through the floor of the furnace. Proper openings must also be provided through both ends of the furnace to allow these attachments to pass into and out of the heating chamber. These blades are invariably made just as light as possible since the upper portion which projects into the furnace and carry the work must be brought up to furnace temperature on each passage through the furnace. Considerable heat is also conducted down through the blade and into the chain. Whether this type of furnace is more economical than the hot chain type is, of course, a question of the relative weights of packs heated and cooled. The most serious objection as I see it, outside of heat losses in the chain, is the necessary openings through the ends of the furnace.

To overcome air infiltration it is usual to operate these furnaces with a comparatively high positive pressure in the furnace at all times and to carry off the waste gases entirely at the two ends. This is rather wasteful of heat especially with the more

expensive fuels and makes it extremely difficult to properly zone the furnace for accurate temperature control.

The chain conveyor and the roller bottom conveyor have both in the past, however, enjoyed one distinct advantage over the walking beam conveyor for pack heating and that is the ease and simplicity of the discharge. However, that advantage has now disappeared due to recent developments in walking beam furnaces.

The walking beam type of furnace conveyor, while the latest type to be seriously accepted and adopted by the mills, is in reality one of the oldest of the furnace conveyor family. In fact, some of the mills were experimenting with walking beams back in the nineties. Nickel chromium alloys were unknown at that time, hence all metal parts in the furnace were necessarily watercooled. Rather tough on the fuel bill, but then fuel was somewhat cheaper in those days than at present. This type of conveyor evidently interested a great many engineers since a review of the patent office records discloses a great variety of inventions along this line. They recognized what we know today from experience that it is in reality the simplest, most reliable and most economical method of handling material through a heated furnace. This is due primarily to the fact that the conveyor pack never leaves the heat zone in which they operate and to the fact that it is a comparatively simple matter to locate the main operating mechanism entirely out of the heat of the furnace where they can operate under normal conditions.

The first walking beam furnace to have any general acceptance in the various production plants in this country was brought out during the war. This furnace was operated by eccentrics on which were mounted tile lined beams which extended into the furnace through slots in the floor. A large number of these furnaces were installed and while they were very limited in size and in the class of work they could handle, they failed to survive largely through poor application and distribution of heat. They were in effect a cold bottom furnace.

In 1919 I developed and placed on the market the first McCann walking beam furnace. This furnace used tile beams since the general nature of the work handled at that time permitted and also since our alloys were not as reliable as they are now and also were prohibitive in price. Several hundred of these furnaces were built during the ensuing years and practically all of them are on the line today heat treating automobile leaf springs, bumpers, front and rear automobile axles, stampings, car wheels, etc.

About three years ago we redesigned our standard furnace to better meet the demands of the sheet and tin mills. The changes made, however, were in detail design and not in principle since I have never seen any good and logical reason for departing from my original ideas. These changes involved principally the substitution of alloy moving and stationary members within the furnace for the old style tile members and the addition of a very effective method of sealing the slots through the floor to prevent the escape of heating gases or the infiltration of cold air should the furnace go entirely off of control during a mill shut down. This furnace has been very successful in the mills for pack and pair heating and normalizing and for annealing and enjoys the distinction of having never been superseded by any other type in any mill.

Up to a few years ago I was the only furnace manufacturer offering the walking beam furnace to the trade. Then a furnace manufacturer brought out a very well designed furnace which gave me something to compete against. While I didn't tell them so, I actually welcomed them in the field since it helped to prove to the trade what I had been preaching alone for years—that the walking beam is the best type and the most efficient furnace conveyor yet developed. We differ radically in general and detail design but the fundamental principles are the same—

No heat is carried out of the furnace by any conveyor pack.

An ideal operating condition for all expensive alloy parts since they are not constantly subject to alternate heating and cooling stresses which stresses rapidly deteriorate alloy.

No excessively large and unsealed openings are required to allow free movement of the conveyor in and out of the furnace.

The advent of mechanical handling equipment in connection with the mills has brought up several new problems in designing pack furnaces. Speed is a prime requisite as is also heating capacity. Furnaces must be of sufficient length to properly heat the greatly increased tonnage the mills can now roll. By all means insist on having your furnaces long enough. The last ones we built were 10 ft. wide by 75 ft. long, the largest ever built we believe, still our customer feels he has yet to buy one too long. Remember a B.T.U. is a B.T.U. regardless of whose furnace it is released in and that there is no mystery regarding the transfer of heat from heating gases to your steel. The only way you can increase the rate of flow from the outside to the inside of a furnace of steel is to increase the difference in temperature between the heating gases and the steel. If your furnace is too short you must therefore resort to an excessive temperature gradient in portions of your furnace which at any slowing up or stoppage of the mill or furnace can only result in burning or excessive scaling of a furnace loaded of expensive material.

We are firm believers in multiple zone control, each zone to be set and accurately controlled to maintain a temperature but slightly over the required delivery temperature.

We are also firm believers in recirculation of the heating gases over and under the sheets since we know of no surer or dependable method of securing absolute uniformity of heating over the entire hearth area. No difficulty whatever has been encountered in maintaining temperatures of from 1400° to 1800° within 10° plus from side to side in furnaces up to 10 ft. wide with top firing only, but with forced recirculation.

I mentioned speed a minute ago. Speed in the modern pack furnace means speed of delivering from the furnace to the mill. Since any loss of time while the sheet is in the open air between the furnace and mill means loss in temperature of the sheet and the possibility of scaling. Also if the roller must wait a few extra seconds between each sheet delivery

there will be quite a loss in the days total production.

In order to obtain the required delivery and conveyor speeds it has been necessary to make some very radical changes in pack furnace design. It is essential that the conveyors on walking beams have sufficient travel to discharge the longest sheet or pack at each stroke. It is also essential that the conveyor control be so arranged that sheets of varying length can be loaded as they come and properly discharged without any manual adjustment of the mechanism and above all the speed of the conveyor and discharge must be as high as possible without moving the sheets on the conveyor when starting and stopping. Conveyor speeds of around 100 ft. per minute are, I believe, usual at the present time.

A recent development which I have recently brought out provides a delivery speed of the sheets at twice the conveyor speed and at the same time has all the advantages of a chain conveyor without its disadvantages. While this furnace departs in some respects from the standard walking beam, pair heater and normalizer, the fundamental principals and all the advantages of the walking beam conveyor are retained.

Due to the long stroke and the necessity of providing positive acceleration and de-acceleration when stopping and starting the conveyor, individual hydraulic drives have been substituted for the usual electric and mechanical drives.

In conclusion, let me state a few fundamental principles that I feel should be observed in selecting continuous furnace equipment.

Of first importance is the heating, since that is the object of the equipment. Accurate and positive means must be provided in the burner equipment, control equipment and in the furnace construction itself so that the furnace is under positive control of the operator at all times.

Next comes capacity. The furnace selected should be of sufficient length to properly and accurately heat the required tonnage without carrying a temperature gradient in any part of the furnace.

And finally select a furnace with a conveyor that does not carry excessive heat out of the furnace, one in which expansion and contraction of all alloy parts are properly provided for, one with a minimum amount of alloy and one which does not throw undue stresses and vibration in the brickwork and steel casing.

▲

Continuous Sheet Mill Furnaces

By A. L. HOLLINGER
Engineer, Surface Combustion Corporation, Toledo, Ohio

▲

Presented before Spring Conference, Combustion Engineering Division of the Association of Iron and Steel Electrical Engineers of Youngstown, O., March, 1932.

The problem of the furnace manufacturer, in fitting into the modern sheet mill requirements, differs somewhat from that of the supplier of automatic rolling equipment. He is not only confronted with the question of the mechanics, of automatic handling, but with the additional and more serious question of heating, at the same time, to a uniformity not approached in the old method of rolling.

The advantage of the continuous method of system of rolling sheets will never be realized to its full degree without heating of a character that approaches perfection. I prefer then, in the limited time which is available, to present, as the result of our studies on the subject, certain fundamental principles of design which must be present to insure the maximum earning power of the installation.

The Sheet Pack Heating Furnace which will ultimately be accepted as standard by the industry, will combine a condition of perfect heating with sound, trouble free, mechanical operation. The problem of heating differs distinctly from that of mechanical operation, and must be attacked from an entirely different viewpoint. The automatic handling, as we see it today, is so spectacular and is so obvious in the savings it effects, that there is grave danger that the furnace designer of limited experience, and much enthusiasm may fail to give the question of proper heating, the full share of attention which it will sooner or later demand.

There is no mechanical correction that can be made to compensate for improper heating either as effected by lack of uniformity or inability to definitely control furnace atmosphere. Other factors being equal, it is here that yield is determined; here that fuel costs are made; here that superior quality on difficult gauges and sizes is established. Finally, at this point in the operation, the additional increment of earning is gained.

The importance of the matter of correct heating cannot be over-emphasized. Fortunately, the fundamentals involved are well established, have been established for years by reason of experience gained in the continuous heat treating field, particularly in the automotive industry where precision is the first requisite. The problem has been that of combining the fundamentals of perfect heating, with the mechanical handling apparatus as applied particularly to sheets.

These essential features that must be incorporated in our design, in relation to their importance, are as follows:

First: Over and under firing; heating the pack equally from the above and below. Only thus can uniformity from top to bottom of the packs be definitely assured, and only by over and under firing can we obtain high production rates with low temperature differentials.

Second: A tight furnace, with no openings top sides or bottom. Waste gases should be taken out only at the ends, preferably through the charge and discharge doors. Fuel rates, on the modern furnace, are low, less than 800,000 B.T.U. per ton heated, and consequently the volume of waste gases is not

great. With a furnace pressure, which varies with the production rates, going to zero during short standby periods, air infiltration, will occur if the furnace is not tight. Atmospheric control is essential, and cannot be maintained where even small leaks are present.

Third: Hearth area for normal production, such; that for practical purposes there is no temperature difference between the furnace, and the work at the point of discharge, and that in no part of the furnace is it necessary to carry a higher temperature than the final finishing temperature. This condition of hearth area, combined with over and under firing, eliminate the possibility of over-heating during short standby periods, and is essential in producing absolute uniformity in the pack.

In considering the desirability of these features, it must be borne in mind that there is a vast difference between a heating condition which, by comparison with old methods of rolling, permits of improved operation, and a heating condition which is the ideal. Conditions which today may be satisfactory by comparison with previous operations, may be far from satisfactory a year from now. Witness the number of furnaces which were installed several years ago, which were satisfactory by comparison with the old methods, which are entirely inadequate when viewed through the eyes of today's experience. You will find that those furnaces of several years ago that come most near meeting today's requirements, or that most easily lend themselves to being adapted to present needs, are those whose design most nearly follows the fundamental principles outlined above. There are furnaces in operation today which are apparently satisfactory, and do not meet all of these requirements. This, however, does not change the fact that the best heating is not possible without following these three fundamental principles. The wise furnace designer will be very cautious in disregarding any of these principles with a construction which compromises even slightly, fundamentals which are so sound.

By comparison, the mechanical means employed to handle the product in the case of a Pack Furnace, involves entirely different considerations. We may say that so far as mechanical requirements go, a furnace must include a mechanism whereby packs may be charged on a table, conveyed through the furnace and then automatically discharged. The conveyor must be of sufficient flexibility to handle a wide range of material, the discharge must be rapid and quick to respond to the demand for a pack.

The devices or methods, that are available, to meet these demands from the standpoint simply of mechanical handling, are numerous. The inclinations of the furnace designer is influenced largely by his training and experience. In developing the mechanical handling equipment for the pack furnace, there exists the opportunity for wide range in the ingenuity and imagination of the designer. The sound principles of mechanics, that may be called into play, cover so great a range, that an almost unlimited field is there to choose from. It is at this point in the development of the Pack Furnace, that there occurs a strong temptation to disregard or at least modify, those principles of heating which are so essential. It is here that that division of our engineering, which is responsible for proper heating conditions, must be constantly on the alert to prevent a compromise in order to accommodate what may be merely an excellent mechanical apparatus.

We cannot for a moment minimize the importance of properly designed mechanical handling equipment which will operate day in and day out with little or no attention. At the same time, we must recognize the fact that unless this operating condition is combined with those fundamentals which provide proper heating, the full justification for the installation does not exist.

We said to our engineers, "Design for us a Pack Heating Furnace which has a tight construction, which may be over and under-fired, and has a mechanism which is adaptable to automatic discharge and high speed operation. If such apparatus does not exist today, do not compromise these essential requirements, but develop then a mechanism which will be adaptable." We found quickly that no mechanism did exist which would, in a satisfactory fashion, meet all of these desirable features of operation. An extensive program of research and development was launched. Many schemes were evolved, any of which met nearly all of the requirements. The problem became more difficult as the possibilities in one idea after another were exhausted. The lack of sufficient data on the performance of heat resisting alloys under certain conditions, was a handicap. The discovery, finally, that alloy beams at high temperature were not effected by sliding in a stool indicated the solution.

Tests greatly exaggerating normal conditions of load temperature and speed were made, to definitely prove the point. A thirty-five foot furnace was built complete with all mechanical equipment and tested under operating conditions in our own development laboratory before we offered a furnace of the following general specifications:

Walking beam conveyor.

Chain type automatic discharge.

No openings top sides or bottoms of furnace structure.

Over and under fired.

I have tried to present to you that certain fundamentals, of design, are necessary to the best heating practice. You admit readily that they are desirable. I maintain, however, that it is not a question of their being desirable, but that from the viewpoint of maximum return from the investment these fundamentals are essential. Forget for the moment types of mechanism, kinds of burners, amount of insulation, and other such details. Do not forget, however, that you may not violate established laws of proper heating without paying a penalty, a penalty which will vary in proportion to the extent that these laws are disregarded.

In conclusion I represent that there is only one sound basis of procedure in the selection of a Pack Furnace. Determine first that those elements which insure the highest quality heating are present in the designs under consideration. Choose, then, from those propositions passing this test the one which offers the best mechanical features based on your experience and that of the builder. This seems a logical conclusion.

The Application of Electric Control Equipment to Roller's and Catcher's Tables

By J. J. MELLON
Engineer, Clark Controller Company,
Cleveland, Ohio.

Presented before Spring Conference, Combustion Engineering Division of the Association of Iron and Steel Electrical Engineers at Youngstown, O., March, 1932.

The preceding papers have been very instructive in outlining the advantages of continuous furnaces and Roller and Catcher's Tables when used in combination. The structural and mechanical features of these various elements have also been very ably presented.

It is the purpose of this paper to discuss the developments in Electric Control apparatus for use on these new elements, with particular reference to the Roller's and Catcher's Tables.

Within the last eighteen months, a continuous development of suitable equipment for these new applications has been going on, in some twenty-three complete installations, located in ten different Sheet and Tin Plate Mills. As these successive equipments were being installed, developments in control, based on experience in the immediately preceding installations, came so fast that hardly any two of these installations are exactly alike. Not only were the difficulties anticipated at the beginning of the development experienced, but also many new problems were encountered. The latest installations, however, give every indication of mature development, and assure the adequacy of the control equipment for this application.

This discussion will be divided into three parts. The first part will cover some of the main factors encountered in the development, which involve unusual problems for electric control apparatus; the second part will outline and describe the control apparatus itself as used at the present time on these tables; and the third part will cover a discussion of other possible methods of meeting this problem.

Plate 1 is a diagrammatic sketch of a Continuous Pack Furnace with Roller's and Catcher's Table. The functions of the Pack Furnace have been completely described in the preceding papers. The use of the Continuous Type Pack Furnace has a direct and important bearing on the proper selection of control equipment used on the Roller's and Catcher's Table.

The Continuous Pack Furnace is designed to continuously deliver a certain tonnage of material at rolling temperature per hour. Allowing material to remain in the furnace an abnormal length of time will cause over-heating of the material, since the temperature of the furnace itself is above the required rolling temperature. Therefore, it is extremely important that delays on the Roller's and Catcher's Tables be very infrequent, and that the apparatus used be capable of quick repair, as long delays might cause serious difficulties.

From the standpoint of the furnace therefore, apparatus used on Roller and Catcher's Table should first of all be selected for its reliability, simplicity and adaptability for quick repair.

An investigation of the frequency of operation of control equipment on these tables, shows that there is a possibility of operation of every piece of this equipment, of approximately 1,000,000 to 1,250,000 operations per month. When it is recalled that not so long ago, 2,000,000 operations of an A.C. Con-

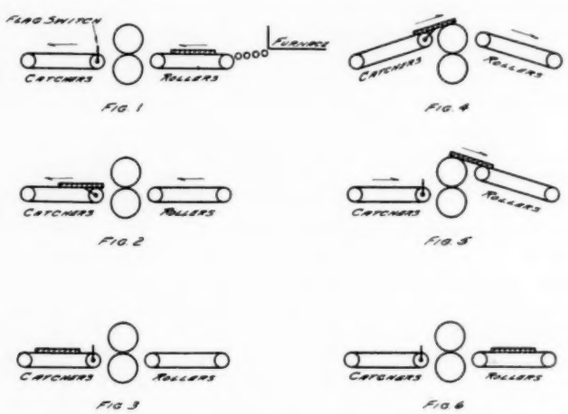


PLATE No. 1—Schematic Layout for Operating Cycle.

tactor was considered good for a commercial switch, the control problem as regards contactor design is evident.

In the early stages of the development, it was thought that adjustable speed was required on the Chain Drive on the Tables. Because of this supposed requirement, tables with D.C. Motors on the chains and A.C. Motors on the tilt, have been built. Still other equipments were built using D.C. Motors, Brakes and Control throughout. Today, A.C. Motors only are used on both the Tilt and Conveyor motions; therefore, this discussion will be limited to control for A.C. Motors only.

Referring again to Plate 1, the position of the piece at the beginning of the cycle is shown in Fig. 1. When the master switch lever is placed in the automatic position, the chains both start to run at the same time in the direction as shown by the arrow, that is away from the furnace. The piece enters the rolls, passes through them, and depresses the flag switch mechanism as shown in Figure 2.

As the rear end of the piece clears the flag switch as shown in Fig. 3, the flag switch moves back to its normal position, and sets up circuits causing the direction of both chains to reverse, so that they now run towards the furnace. At the same time, the Catcher's Table is tilted and this tilting,

in turn, causes the Roller's Table to be tilted. The piece now moves back toward the rolls, again depressing the flag switch, but this time in the opposite direction as shown in Fig. 4.

PLATE No. 2—Magnetic Control Panel for Roller and Catcher Tables.

After the rear end of the piece has cleared the flag switch, as shown in Fig. 5, the flag switch again resets and the Catcher's Table tilts downward immediately. When it is part way down, it sets up a circuit which starts the Roller's Table down, and this interval permits the rear end of the piece to clear the top roll before the Roller's Table moves down. Both chains are automatically reversed when the Roller's Table reaches a certain position in its downward motion, thus completing the cycle as shown in Fig. 6, which is similar to Fig. 1. This automatic operation continues until the master switch operating lever is brought to the center position.

Plate 2 shows a typical Roller's and Catcher's Table control panel. The small number of contactors and relays to accomplish this automatic operation indicates a desire for simplicity in control to minimize the tracing difficulties in case of improper operation. This board is practically the same, whether the control circuits be A.C. or D.C. operated except for the interchangeable contactor magnetic circuits.

The contactors used in this panel are of special design, in order to withstand the number of operations that this application demands. Contactors of similar design have already been in service about a year on these tables, with very satisfactory results. It is estimated that during the year, the contactors performed about 10,000,000 operations. Developments now under way contemplate a still further modification of the design to accomplish 20,000,000 operations with either A.C. or D.C. Magnetic Operating circuits.

The advantages of A.C. control with A.C. Operating Circuits and A.C. Brakes, fundamentally lie in the speed of operation and the use of only one power source.

The disadvantages, which are at first apparent, are due to the operating characteristics of A.C. Magnets, such as are used on contactors and brakes. Considerable slam is experienced when the magnetic circuit closes, and considering the frequency of operation, increased wear and crystallization of the parts might be expected. The magnetic circuit of an A.C. Brake or Contactor, is quite complex when compared to a similar D.C. Brake or D.C. Contactor.

Early in the development, it appeared that if proper operation could be obtained with D.C. Operated A.C. Contactors and D.C. Brakes; the undesirable features of the complete A.C. equipment would then be eliminated. Comparative tests on D.C. Brakes and A.C. Brakes, and likewise on D.C. and A.C. Contactors, however, showed that D.C. Magnetic Circuits were much slower than A.C. Circuits, and it appeared that this idea would prove impractical.

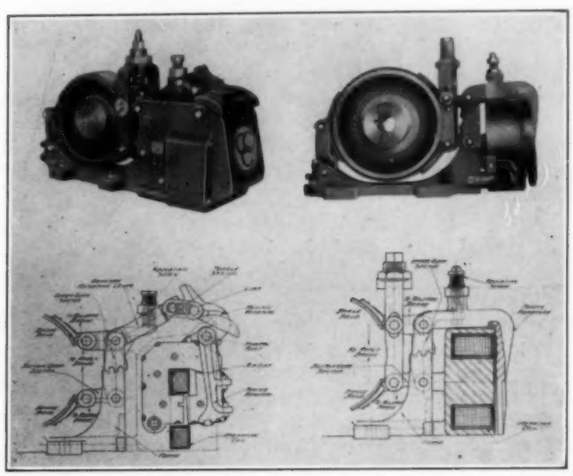


PLATE No. 3—Tilting Motion Magnetic Brakes—Contrast of A.C. and D.C. Types.

On Plate 3 an A.C. Brake and a D.C. Brake, as now developed for Sheet Catcher work, are shown. Below each brake, a schematic sketch of the magnetic circuit in these brakes, illustrates the simplicity of the D.C. Brake when compared to the A.C. Brake, and furthermore the slam when the magnetic circuit closes is much less with the D.C. Brake than it is with the A.C. Brake. Experimentation with the D.C. Magnetic Circuit showed that by using a special coil and a special magnetic circuit, it is possible to build a D.C. Brake fast enough to operate on the tilt motions of these tables. Many of these D.C. Brakes are now in successful operation.

The same line of reasoning can be applied to the contactors and relays used in conjunction with the tilt motion, and it can be demonstrated in a similar manner, that due to the intermittency of service on this application, high speed D.C. operation is possible. On the reversing contactors on the chain drive, a more difficult problem is evident. Investigation shows that the forward and reverse contactors are each in practically 50% of the time; and furthermore, extremely fast reversal is desirable on the Catcher's Table, after the flag switch resets. This difficulty has been successfully overcome by a special operation as follows:

Let us assume that the piece coming through the rolls depresses the flag switch as the front end

passes over the switch. At the moment this switch is depressed, relays are actuated which energize the reverse contactor on the chain motion, even though the forward contactor is still in. The reverse contactor cannot close at this time, however, as it is mechanically interlocked with the forward directional contactor. When the limit switch is still down, relay sequence circuits change the set-up so that the forward directional contactor is held in only through the flag switch contacts. As soon as the flag switch resets, the coil circuit of the forward contactor is broken by the flag switch directly, and the reverse contactor actually pushes the forward contactor out and closes itself.

To accomplish this unusual operation, it is not possible to use a standard mechanical interlock, as normal mechanical interlocks are designed for emergency operation only. On Plate 2 you will note the special heavy mechanical interlock which is used. This interlock is made up of a heavy cast steel bar supported by a heavy brass casting, the pivotal point being made with a large nitralloy pin and bushing. The points where the bar bears on the pins connected to the reversing contactors, are hardened.

The reversal with this set-up was so fast on the first installation, that it was difficult to keep the piece from hitting the rolls before the table was tilted. Adjustment of this reversal has made it possible to obtain minimum over-travel on the Catcher's Table with this equipment. The D. C. Magnetic Circuit on the contactors as shown, is very simple when compared to the A.C., and is interchangeable with the A.C. Magnet. 3-Pole Contactors are used throughout entire applications, assuring that all three lines to the motor are opened at the same time.

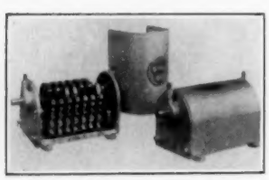
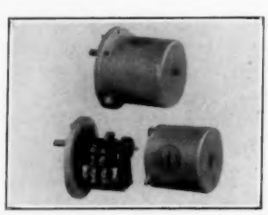


PLATE No 4—Tilting Motion Limit Switches—Ball Bearing Drum Type.

PLATE No. 5—"The Brains of the Controller"—The Flange Type Flag Switch.



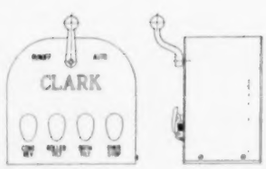


PLATE No. 6—Operating Master Station Providing Complete Control of Tables.

D.C. and A.C. No-Voltage Relays are used so that no voltage protection is obtained, regardless of whether the failure be in the A.C. or D.C. source.

One of the large Steel Companies that pioneered the development of this equipment has always insisted on A.C. operated A.C. control, and A.C. Brakes. This insistence has resulted in such a pronounced advance in A.C. Contactors and A.C. Brakes, that today there is very little, if any, difference in the operation and performance of the two methods of operation.

It is necessary that a suitable limit switch, having a number of contacts, be connected to each tilt motion. On the earlier installations, this consisted of one or two steel cams, with adjustable bumpers, operating standard hatchway limit switches.

Experience with these indicated that a geared type limit switch of suitable construction would be a big improvement in the design. Plate 4 is one design of limit switch now being used for this application. The feature of this switch is its positive wiping contacts which are so essential to the operation on these drives. The fingers are similar to 75 ampere drum controller fingers, and are held with heavy spring pressure against copper drum segments. Each segment is independently adjustable as to position on the shaft. These contacts carry only control currents. The switch is ball bearing and is of such construction that all flexible shunts are eliminated, and any mill electrician, by inspection, can note excessive wear and easily make replacements.

The flag switch is unquestionably the most important and difficult application on the table. In early designs, the trigger was placed near the front end of the table, and connected to a knuckle which pulled a rod operating a standard hatchway limit switch, located near the pivot where the table tilted. Positive contact could not always be obtained, and breakage of flexible shunts and wear of the small parts caused considerable difficulty with this design. Since after the master switch is placed in the automatic position, all operations are controlled from the flag switch, it is evident that any difficulty at all with the flag switch is serious.

Plate 5, a design of flag switch is shown which is now in use and which gives promise of eliminating the difficulties with this device. Every effort was put forth to make this switch simple and rugged, and to eliminate small moving parts. Your attention is called to the heavy cast flange construction of the switch, and the heavy drum fingers, and the sliding copper contacts. The switch is ball bearing and arranged with two bearing supports. Flexible shunts are absolutely eliminated from the design. The switch is mounted on the side of the table by the flange, and is so located that it can be regularly and readily inspected, and evidence of wear which would cause ultimate failure, can be noted far in advance of such failure. The wiping action of the contacts assures positive contact regardless of dirt or dust conditions in the mill. The wearing parts are of such material that emergency spare parts can be made up in any Steel Mill electrical shop. The wearing parts, except the drum segments themselves, are duplicate on the flag switch and the tilt limit switch.

The operation of this equipment is controlled entirely from a master panel, which is similar to that shown in the layout on Plate 6. The master switch shown near the top is two-position only; one position for automatic operation, and the other for the run-off operation. In the off-position of this master switch, all motion of the Roller and Catcher's

Table stops. In normal operation, with a piece on the table, the master switch is put in the automatic position, and the piece continues to go back and forth through the mill until the operator is ready to run it off. Sometimes the master switch is brought to the off position, and the roller measures the piece before setting the screw for the last pass. The master switch is then placed in the run-off position and the piece goes through the rolls, on to the Catcher's Table, and on out to the run-off device, without tilting the table. On the run-off position, the flag switch is ineffective. In the earlier designs, another intermediate point was included on the master switch, which was called "Pack Out," which also started a piece out of the furnace when the master switch was in this position, as well as starting the run-off operation. It was later shown that this caused delay in bringing the piece out of the furnace, as it limited the time for this motion to the time when the piece was being run off.

Under the master switch, it will be noted that there are four palm-operated push buttons, which are all for emergency operation. These buttons are covered with a cast aluminum operating plate, which makes it possible for them to be operated easily by a man wearing heavy gloves. One push button tilts the roller's table, one the catcher's table, one reverses the chains, and the other is an emergency stop button which will clear the Roller's and Catcher's Panel from all electrical circuits. This button may also be used to stop all motions in the furnace, except the blower, in case of emergency. The blower must not be stopped, even in case of emergency, from the operator's master panel.

During the development of this equipment, and before the use of the special interlock apparatus on the chain control, considerable over-travel was noted on some installations on the Roller's Table. Since it was not possible to start reversal before the flag switch assumed its vertical position, some little time elapsed while the relays and contactors were rearranging themselves for reversal, and meanwhile the material continued to move away from the rolls. It appeared that by using another flag switch on the mill end of the Roller's Table, in conjunction with the timing relay, that after the end of the piece had cleared the flag switch on the Roller's Table, it would be possible to allow a certain time to elapse, giving the material time to get through and clear the rolls on the far side, and then the table would tilt and reverse. In this way, it appeared that minimum over-travel on the Catcher's Table would result.

A further consideration of this proposal, indicated that this scheme probably was not the best solution. Since the main rolls on many Sheet and Tin Plate Mills are driven by steam engines, slip ring motors, and other variable speed drives, the main roll speed is constantly changing. This means that if the timing relays were adjusted for minimum over-travel, and if the rolls slowed down after the rear end of the piece had cleared the flag switch on the Roller's Table, the piece would be longer in getting through the rolls, and the timing relay allowed, and the catcher's table would tilt with the piece in the rolls, or at least the rear end of the piece would not clear the rolls. This might cause a cobble which would take some time to clear.

By studying existing installations and determining the maximum slow down possible on the main rolls, the timing relay could be adjusted to have sufficient timing to take care of this condition. If this adjustment were made, however, then on normal operations when the rolls did not slow down very much, considerably more over-travel on the Catcher's Table would be obtained than necessary. The development of the quick-reversing chain drive, however, eliminates the necessity of the second flag switch, in the opinion of many now using these equipments.

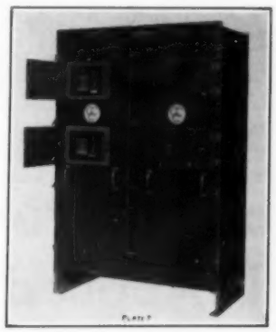


PLATE No. 7—Special Dust Tight Cabinet with "Lift-Off" Doors.

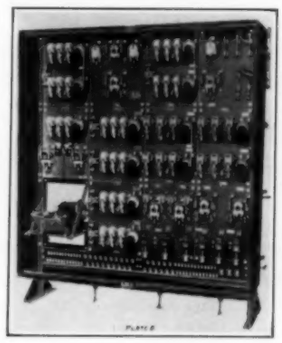


PLATE No. 8—Double Pack Furnace Control Panel.

On some installations, timing relays have been used for sequence control, but on many of the latest installations, all timing relays for sequence are omitted for the sake of simplicity, and adjustments of chain reversal, tilting and all other automatic adjustments are adequately taken care of by adjustment of the limit switches. These adjustments are permanent when once set, and do not have to be adjusted frequently.

There has been some discussion as to whether or not the control panel used on these installations, should be enclosed in standard sheet steel cabinets or in dust-tight cabinets. Since these panels are usually installed out in the mill, it is evident that anything which positively prevents dust and dirt from entering the cabinet and thus keeps the bearings clean, will result in much longer life of the control parts. Since dust-tight cabinets do this, it appears that their use is justified.

Plate 7 shows a dust-tight cabinet design which is now being used on these panels. Overload protection and disconnect features on this panel are accomplished with Urelites. Arrangements are made

so that the Urelites can be operated without taking the main covers off. On cabinets of similar design where Urelites are not used, externally operated knife switches with provision for locking in the off position are included. In case it is necessary to remove the covers, one man can easily remove the door, by unloosening the wing nuts and picking the door up and off of the cabinet. The wing nuts are an integral part of the cover and are not lost when being removed. The angle on the top of the cabinet serves as a guide for the door, so that the door can be easily replaced by one man.

The control equipment on all drives on the furnace, except the blower, is interlocked, and many users feel that this equipment should be enclosed in one large cabinet, with interlocking, and be of the same quality material as used on the Roller's and Catcher's Table that it is used with. Plate 8 shows a typical furnace controller ready for operation.

The design of the electric control equipment should be so co-ordinated with the mechanical and motor design of the entire installation, that a continuous stream of material will be fed into the Pack Furnace, through the Furnace, and brought quickly down to the Roller's and Catcher's Tables and rolled, without delay at any point. It is of no avail to save tenths and hundredths of seconds on the Tilt and Chain Motions of a Roller's and Catcher's Table, only to waste full seconds waiting for material to be delivered from the furnace to the Roller and Catcher Table. The entire installation of the unit has but one object and that is, more tonnage per turn, every turn.

▲

The Squirrel-Cage Induction Motor As Applied To Starting, Reversing and Stopping Duty

▲

By E. W. HENDERSON
Design Engineer, Reliance Electric & Engineering Company, Cleveland, Ohio.

Presented before Pittsburgh District Section, Pittsburgh and Spring Conference, Combustion Engineering Division, of the Association of Iron and Steel Electrical Engineers at Youngstown, O., March, 1932.

The squirrel-cage motor has long been considered a constant speed motor and one to be started but seldom. Recently, squirrel-cage motors have been successfully applied to fields of operation usually thought of as those belonging strictly to d.c. mill type motors. The purpose of this paper is to bring to your notice some of the important things to be considered under such applications, and to give you something that may assist you in solving problems of this kind.

When a motor starts up under load, it must do two things, viz, (1) exert a torque to overcome the resisting friction or load torque, (2) accelerate all the moving parts from rest and bring them up to their final velocities. Now, if a motor application is such that the motor starts very infrequently, such as once or twice a day, the accelerating torque is of little consequence and the power required and expended during acceleration has little to do in determining the final temperature of the motor. If, however, the motor must start frequently, such for example as several times each minute, then the energy of acceleration will be relatively large and becomes of prime importance in determining the final temperature rise of the motor.

Suppose Figure 1 represents the energy loss in a motor under starting and running conditions. In this figure "t_1" represents the starting or accelerating period and "t_2" represents the running period. Let the power loss during acceleration be 20,000 watts and during running be 2,000 watts. If t_1 = ½ second and t_2 = 5 hours or 18,000 seconds, then the total loss in watt-seconds equals

$$.5 \times 20{,}000 + 18{,}000 \times 2{,}000 =$$
$$10{,}000 + 36{,}000{,}000 = 36{,}010{,}000 \text{ watt-seconds}$$

The total time is 18000.5 seconds and the average loss equals

$$\frac{36{,}010{,}000}{18{,}000.5} = 2000 \text{ watts practically.}$$

In other words, the accelerating loss has added little to the average total loss over the whole operating period. However, if t_1 equals ½ second and t_2 equals 1 second, then the average loss equals

$$\frac{.5 \times 20{,}000 + 1 \times 2000}{1.5}$$
$$= \frac{10{,}000 + 2000}{1.5} = 8000 \text{ watts}$$

If the motor was used on the latter cycle, the heating would be much in excess of the former since it would have to dissipate four times the loss of the longer cycle. The importance of the loss during the accelerating period is thus very apparent.

One of the most interesting applications of squirrel-cage induction motors for rapid and oft repeated reversing duty is that on automatic catcher and roller tables used for rolling sheets or packs. The first tables of this type were developed by the American Sheet & Tin Plate Company at Gary, Ind. D.C. motors were used on the first tables. Later came a demand for squirrel-cage motors and special

motors have now been in successful operation in Gary over a year. Motors in some twelve other plants have been in operation a shorter period and with entire success. These motors will withstand forty reversals per minute without excessive temperature rise.

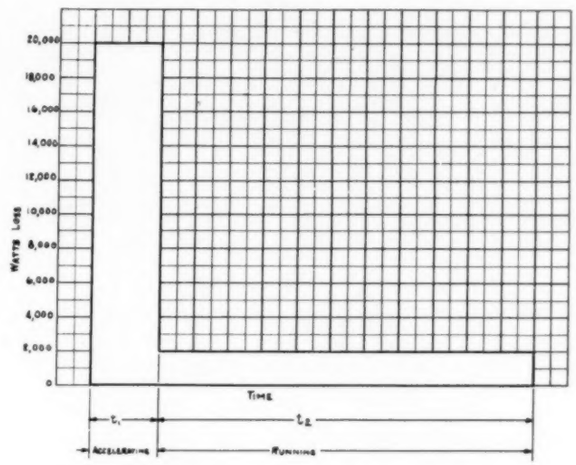


FIG. 1—Watts-loss Diagram showing Main Parts of a Cycle.

Before going into the details of this operation, let us look at some of the advantages of a squirrel-cage rotor for reversing service, especially as compared to d.c. armatures. The WR^2 of a standard 20 hp. d.c. motor armature at 850 r.p.m. is approximately 35 lbs. ft^2. The WR^2 of the rotor in a squirrel-cage motor of the same rating is approximately 16 lbs. ft^2. Not only is the normal WR^2 of the a.c. machine less but it is naturally simple to make that of the a.c. rotor considerably less than that of the d.c. armature. The d.c. machine must carry well insulated windings with increased weight for end connections, banding, slot insulation, etc. It is subject to shorts and breakdowns. The a.c. rotor has no insulation and its construction makes it practically indestructible. The a.c. motor has no troublesome commutator, brushes, and brush rigging, requiring renewal or maintenance. The iron below the slot can be much less in the a.c. than the d.c. armature since the d.c. machines are, as a rule, either 4 or 6 pole machines, whereas the a.c. machines of slow speed run two to three times this number. The WR^2 of the a.c. rotor can thus inherently be much less than that of the d.c. armature with its necessarily greater core weight and commutator weight. The whole a.c. motor is smaller, conserves space, is cheaper, faster in operation, more simple and more rapid in control, and much more economical in control.

The only advantage the d.c. motor has lies in its ability to put some of the loss inherent to reversing duty outside of the motor. The squirrel-cage motor must spend it all in the motor itself. But from the standpoint of ruggedness, dependability, and adaptability to rapid reversing service the squirrel-cage rotor has much in its favor. It is being used extensively in many classes of service where repeated reversing is necessary and will, in the future, be still more widely applied for similar operations.

Automatic catcher and roller tables are used in the rolling of sheets or packs. The process starts from a bar approximately 8″ wide, 18″ to 30″ long, and ½″ thick, depending on the ultimate size of sheet to be produced. These bars are heated to rolling temperature in what is known as a "pair" furnace. They are generally charged in the rear of the furnace by means of a mechanical pusher and in the hand-type mills are withdrawn at the front by a man called the "heater" who uses a long pair of tongs for this purpose. Two bars are withdrawn at a time, giving us the reference to "pairs".

This pair of bars is passed to the "roller" who stands at the front of his mill. It is necessary for him to raise these bars from the floor level to the entrance between the rolls. As they emerge on the opposite side of the mill, another man called the "catcher" catches the piece and raises it manually to the top face of the upper roll where the "roller" again grasps it with his tongs and lowers it into the mill for another pass. Each bar is run through in this manner. After sufficient passes, these single bars are placed one on top of the other and passed through the mill together. Again, after sufficient passes, this pair is "doubled" by bending it over on itself at the middle and thus becomes four units thick. The doubled sheets are now called a pack. Most of the operations up to this point are done on what is called the "roughing mill" although the pass prior to doubling is often made on the finishing mill. There are in use automatic catcher tables for these roughing mills, arranged to carry the slabs, but the ones to which I wish to draw attention are the automatic tables used in connection with the "finishing" mills.

After doubling, the pack is reheated. It is conveyed to the rear of the reheating furnace on a chain conveyor and fed automatically into the furnace. A great deal of the improvement in the process of making sheet has been made in these furnaces.

They are no longer hand loaded. The entire process is automatic. Conveyors of some description carry the packs or sheets from the entry at the rear of the furnace to the exit at the front end of the furnace. The heat of these furnaces is thermostatically controlled and results in sheets well and evenly heated. The use of automatic catchers has made it necessary to increase the length of these furnaces many times over that of the type used for manual rolling and catching.

As the sheet or pack emerges from the furnace, it is conveyed on to an automatic "rollers" table of a type shown in Figure 2. You will note there are two motors shown on this table. The motor mounted about centrally under the table drives a crank, through a reducer, and the rotation of this crank tilts the table up and down as desired. The other motor shown at the end of the table drives the chain conveyors indicated, through a reducer also. The speed of the mill usually approximates 240 ft. per minute and the conveyor chains are run at about this same speed. The control is arranged for manual or automatic operation. The sheet comes on to the roller's table while it is in the "down" position, passes through the mill and is received on the catcher's table, Figure 3. The tables tilt upward, the conveyors reverse and the material is transferred to the roller's table which again tilts

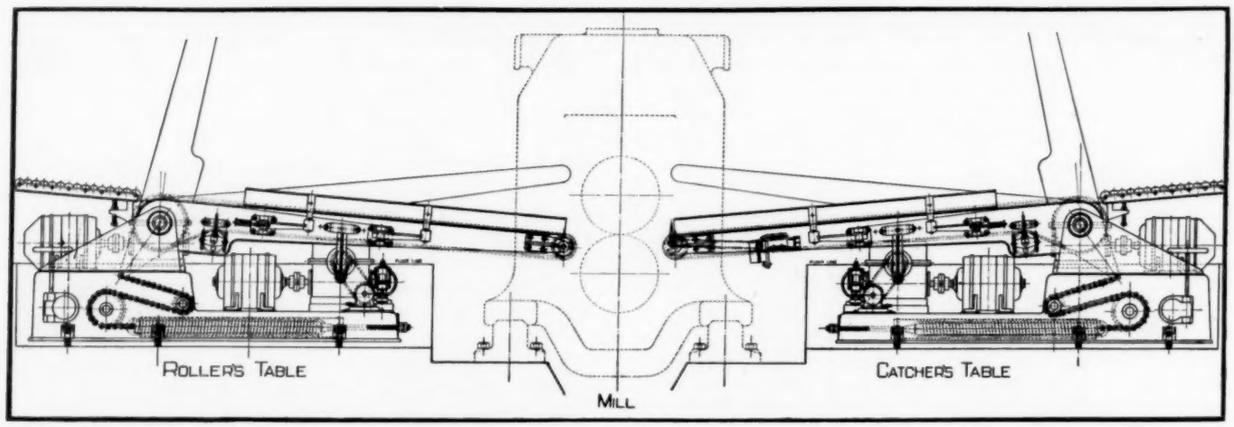


FIG. 2—Automatic Rollers Table for Handling Sheets or Packs.

FIG. 3—Automatic Catchers Table.

downward and the operation is repeated as often as desired. The use of continuous furnaces and this type of automatic handling of the sheets has made possible an increase of tonnage of approximately four hundred per cent. Not only is tonnage increased but the quality of the steel is improved by better heating, better rolling and improved handling.

The motors used on such tables are designed with all the necessary provisions for low loss mentioned in the latter part of this paper. The rated speed is low, being 375 r.p.m. synchronous for 25 cycle motors and 450 r.p.m. synchronous for 60 cycle motors. The rotors are of special light construction but withal rugged and serviceable. The motors are of the enclosed type so popular in places where dirt is inevitable. Figures 4, 5, 6, 7 and 8 show the motor construction. The fans are cast duralumin,

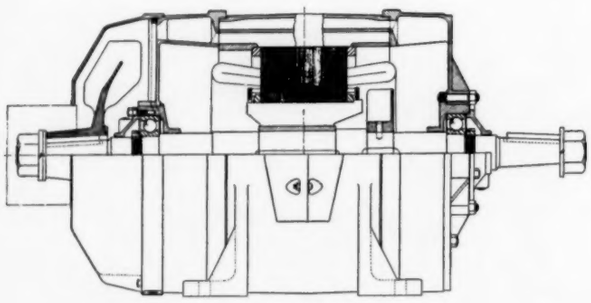


FIG. 4—Details of a Low-Inertia-Rotor Motor Showing Liberal Radiating Surfaces, and Other Features Demanded for Quick Reversing.

heat-treated for further strength. The keyways and hubs are especially liberal. The rotor core is reduced to a minimum. The stator end connections are braced against magnetic mechanical forces and the stator winding is of low resistance for minimum loss.

The tilt motors are identical in mechanical construction except that the outer fan is omitted. It is sometimes desirable to have the motors interchangeable. Our construction has been made especially with this in view. On account of the heavier torque requirements of the tilt motors and the lower loss in accelerating as compared with reversing, as explained later, in equations 3, 4 and 5, the tilt motors are sometimes given more torque than the conveyor motors. On account of the high ambient temperature we recommend asbestos covered wire for the stator windings.

The catcher's table is very similar to the roller's table, but carries at its end nearest the mill a trigger switch which is the main control feature of the equipment. Through a master controller manually operated by the roller, the table can be set for automatic operation and when so set the controls are completed through this trigger switch on the catcher's table to follow in natural sequence. When the master is set for non-automatic operation the con-

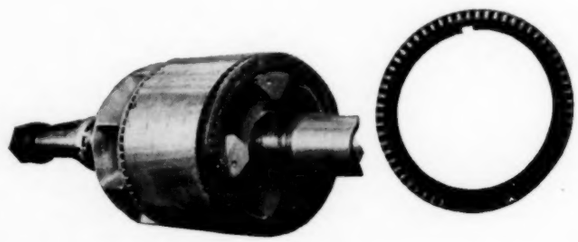


FIG. 5—A Low-Inertia Rotor.

veyors run the pack off the tables and receive another one for rolling. The automatic cycle of receiving it on the catcher's table, the tilting upwards of the tables, reversal of the conveyors, transfer of the pack over the top roll to the roller's table, and the downward tilt of the tables to their original position with the conveyors again reversed to carry the pack into the mill, is repeated until rolling is complete.

In the above cycle it will be noted that the conveyor motors reverse twice in each cycle and that the tilt motors start up twice in each cycle. In order that the action of these motors may be sufficiently fast and the losses incident to the cycle be sufficiently low and of such a magnitude as to be radiated by the motor used, it is essential that certain properties of these motors be looked into with great care. Let me point out some of the important things to be considered when acceleration or retardation have to be taken into account.

The value of constantly applied torque which is

necessary to accelerate a mass from rest up to a given speed is expressed by the equation

$$T_a = \frac{WR^2 \times RPM}{308 \times t_1} \quad \ldots\ldots(1)$$

where T_a equals accelerating torque in pounds feet.
WR^2 = mass in lbs. ft²
RPM = final speed
t_1 = accelerating period in seconds.

The above equation assumes that T_a is constant over the entire period "t_1". The equation may be turned around so that

$$t_1 = \frac{WR^2 \times RPM}{308 \times T_a} \quad \ldots\ldots(2)$$

and expresses, in this form, the time required to accelerate the mass for the given change in speed and constant accelerating torque.

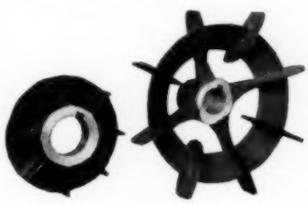


FIG. 6—Low-Inertia Fans, Showing Liberal Hubs and Keyways.

In the case of a motor accelerating a connected load, the WR^2 must include that of the rotor and of all the connected moving parts. It is generally convenient to refer the WR^2 of the connected parts to the motor speed. Suppose a certain connected part, say a gear, has a final speed of 200 r.p.m. and a WR^2 of 400 lbs. ft². The force to accelerate this to its speed in one second equals

$$\frac{400 \times 200}{308 \times 1} = 260 \text{ lbs. ft.}$$

If this is accomplished through a motor running at 1000 r.p.m., the power must be the same in each case and therefore the torque on the motor would be $\frac{200}{1000} \times 260 = 52$ lbs. ft. However, 52 lbs. ft. is the force which would accelerate to 1000 r.p.m. a mass of $WR^2 = \frac{52 \times 308 \times 1}{1000} = 16$ lbs. ft². In other words, accelerating 400 lbs. ft² to 200 r.p.m. is equivalent to accelerating 16 lbs. ft² to 1000 r.p.m. But,

$$\frac{16}{400} = \left(\frac{200}{1000}\right)^2 = \left(\frac{\text{driven speed}}{\text{motor speed}}\right)^2$$

Similarly, all other connected parts must be referred to the motor speed in the ratio of

$$\left(\frac{\text{driven speed}}{\text{motor speed}}\right)^2$$

Having determined the total WR^2 of the motor and connected load, the necessary torque can be found to accelerate this mass in any required time. Note particularly that this torque varies directly with the final speed and the total WR^2, and inversely with the time. (See equation 1).

In the case of an induction motor, the torque cannot be of a constant value from standstill to running speed. The torque depends on the flux of the motor, the number of rotor conductors, the current in these rotor bars and the phase relation be-

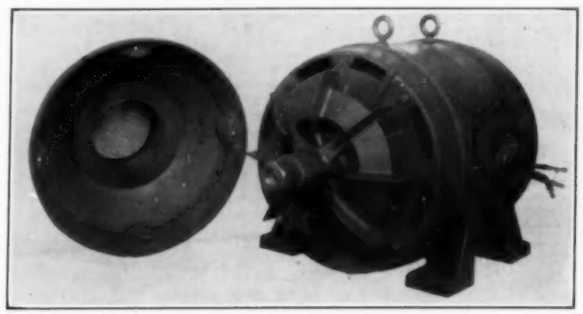


FIG. 7—Motor for Reversing Duty, Showing One Method of Holding Outer Fan.

tween the current and flux. The current and phase relation depend on the rotor-bar resistance and are continually changing as the motor speeds up from standstill towards synchronism. The counter e.m.f. and flux also change so that the torque of an induction motor cannot be constant. Figure 9 shows characteristic torque curves of an induction motor. Curve A indicates the torque characteristic obtained with an induction motor having a rotor of low resistance. Curves B and C represent the torque curves of motors having rotors of higher resistance than A, the C curve having the highest resistance of all three.

Obviously, if each of these motors was applied to accelerate a given WR^2, the time of acceleration

FIG. 8—Completely Assembled View of Motor for Catcher Table Service.

would be different for each type of rotor used. Let us work out what the time would be for each case in the hope that doing so will enable you to make more use of such torque curves. From equation (2)

$$t_1 = \frac{WR^2 \times \text{change in RPM}}{308 \times \text{torque producing the change in RPM}}$$

A practical method is to divide up the torque curve into a number of equal increments, say 10, and from the average torque for each increment, calculate from the equation above the time to produce the change in speed represented by the incremental r.p.m. Add up all these intervals to get the total time. Since in each of these calculations the only

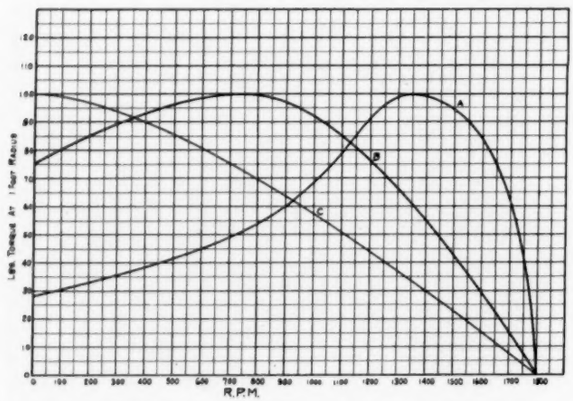


FIG. 9—Characteristic Speed-Torque Curves of Various Types Induction Motors.

variable is the torque, the shorter method, if the total time only is required, is to find the average of the inverse of the torque values. Thus, find the torque corresponding to this average inverse value and use this as the average torque to obtain the total time. This is done by taking the torque for equal increments of speed, finding the reciprocal of each of these, finding the average of these reciprocals and then finding the number whose reciprocal is equal to the average reciprocal. This number will be the average torque. For example, take the values of torque for curve B of Figure 10 second line.

Torque	$\frac{1}{\text{Torque}}$
79.8	.01250
87.8	.01137
94.	.01062
98.5	.01013
99.7	.01002
94.	.01063
81.5	.01226
65.	.01538
44.5	.02245
21.0	.04760
Total =	.16296

$$\text{Average reciprocal} = \frac{.16296}{10} = .016296$$

$$\text{Average Torque} = \frac{1}{.016296} = 61.3 \text{ lbs. ft.}$$

$WR^2 = 30 \sim$ R.P.M. = 1750 ~ Torque As In Fig. 9

Period	0-175	175-350	350-525	525-700	700-875	875-1050	1050-1225	1225-1400	1400-1575	1575-1750	
Avg. Torque A	50	54.5	59.5	45.5	59	64.5	84	98.5	95	72.5	
B	79.8	87.8	94	98.5	99.7	94	81.5	65	44.5	21	
C	94	94.9	88	79.8	70	89.5	43	34.5	24	11	
Acceleration Time A	.568	.434	.431	.376	.322	.364	.293	.171	.179	.255	Total Time = 3.243
B	.234	.194	.181	.175	.171	.181	.209	.242	.385	.810	= 2.788
C	.172	.180	.194	.214	.264	.286	.394	.459	.710	1.550	= 4.419
Average Torque During Acceleration Period From Rest To 1750 R.P.M. = 350/1750 Synch. Speed =	A 52.2										
	B 64.5										
	C 59.6										

Note That These Values Of Average Torque Are Entirely Different From What Would Be Obtained By Averaging The Values Given In The First Three Lines Of The Above Table.

FIG. 10—Tabulated Results of Torques Taken from Fig. 9 and Calculation of Time of Acceleration and Average Torque.

$$\text{Total Time} = \frac{WR^2 \times \text{Final RPM}}{308 \times \text{Avg. Torque}}$$

$$\text{For Fig. 3} = \frac{30 \times 1750}{308 \times 61.3} = 2.78 \text{ seconds}$$

(Check with the values obtained in Figure 10)

This method is shorter than that indicated in Figure 10, but the values of Figure 10 are useful if an acceleration curve is required to indicate the variation in acceleration over the speed range.

The effect of the shape of the torque curve in the time of acceleration is clearly indicated from the data of Figure 10.

For a given maximum torque of an induction motor, it can be shown that the value of starting torque required to accelerate a given WR^2 in the shortest possible time depends on the final speed desired and follows the values shown in Figure 11. A little thought will make Figure 11 understandable. Evidently, if one intends to accelerate from rest to 10% of synchronous speed, the useful torque should be its maximum value; so that the starting torque should be equal to the maximum torque. Similarly, if the acceleration is to be up to 50% synchronous speed the maximum torque should come between starting and the 50% speed. The starting torque will be in value very nearly equal to the maximum torque. As the percentage of synchronous speed is increased the ratio of starting torque to maximum torque falls off until for 95% synchronous speed the

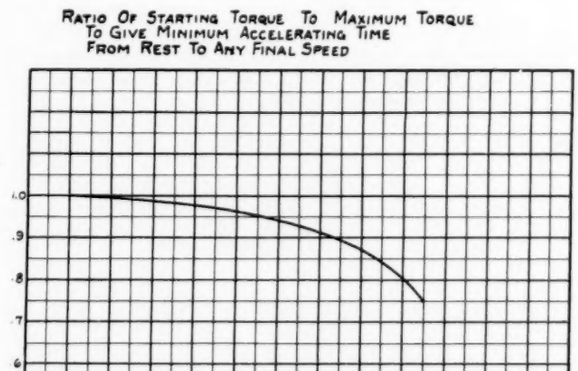

Ratio Of Starting Torque To Maximum Torque To Give Minimum Accelerating Time From Rest To Any Final Speed
1.0
.9
.8
.7
.6
.5
.4
0 10 20 30 40 50 60 70 80 90 100
Final Speed In Percent Of Synchronism
Curve Compiled From Data Of Fig. 3 P 373 A.I.E.E. Trans. Vol. XLV - 1926

FIG. 11—Ratio of Starting to Maximum Torque to Give Minimum Time of Acceleration to Various Percentages of Synchronous Speed.

starting torque for minimum time is about 75% of the maximum value. A study of the figures in Figure 10 will make this more readily understood.

The importance of the shape of the torque curve to obtain minimum time of acceleration is, therefore, evident and it is clear that as far as acceleration is concerned, motors having characteristics such as B and C are superior to motors maving a characteristic similar to A. See also equations 6 to 11.

When a motor is reversed, the shape of torque curve is important if the reversal is to be accomplished in minimum time. Figure 12 shows the torque curves of Figure 9 extended to cover the retardation period when induction motors are plugged on reversal.

The time taken for the motor to come to rest will be much greater for A than for B or C and will be the shortest for curve C. It is therefore necessary, if quick reversal is required, to have the starting torque about equal to the maximum torque.

So much for the question of the torque necessary to accelerate or retard a given WR^2. Let us look at the energy loss to be taken care of under conditions of acceleration and reversal.

You are all familiar with the expression for the energy in a body of mass "m" moving with a velocity "v", as = $\frac{1}{2}$ mv^2. In terms of rotating bodies this becomes.

$$\frac{1}{2} \times \frac{WR^2}{32.2} \times \left(\frac{2 \pi \text{ RPM}}{60} \right)^2 = .00017 \times WR^2 \times RPM^2 \text{ ft. lbs.}$$

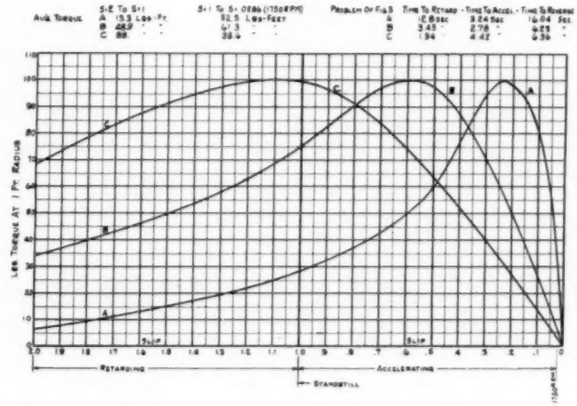


FIG. 12—Speed Torque Curves of Induction Motors for Slips Corresponding to Retarding (By Plugging) and Acceleration to Full Speed.

or, since 1 ft. lb. = 1.357 watt-seconds, the energy represented by rotation becomes Kinetic Energy = .000231 x WR^2 x RPM^2 watt-seconds.

It can be shown that the energy lost in the rotor of an induction motor in accelerating a mass WR^2 is $P = .000231 \times WR^2 \times (RPM)^2 (S_1^2 - S_2^2)$ watt-seconds where "S_1" is the initial slip and "S_2" the final slip.

The slip is expressed as the ratio of

$$\frac{\text{Syn. Speed} - \text{Actual Speed}}{\text{Syn. Speed}}$$

When a motor starts from rest S_1 equals 1; when a motor reaches synchronism (approx.) S_2 equals 0.

Therefore, the loss in the rotor of an induction motor when the rotor and its connected load are accelerated from rest to a speed near synchronism is

$P_a = .000231 \times WR^2 \times (RPM)^2$ watt-seconds .....(4)

Since equation (4) is identical with the expression for the kinetic energy in the body when up to speed, as deduced above, we conclude that the energy necessary to expend on the rotor is twice its kinetic value. In other words, the transformation has an efficiency of 50%. We lose an amount of energy equal to that which remains in the body due to its rotation. Discussion is invited if this is not plain.

Similarly, when a motor is reversed $S_1 = 2$, $S_2 = 0$ and the loss in the rotor is

$P_r = .000231 \times WR^2 \times RPM^2 \times 4$ watt-seconds .....(5)

Note particularly that this is four times the loss when accelerating only.

Equations 4 and 5 represent the energy loss in the rotor only. In order to account for the losses in the stator also, which comprise copper loss and iron losses, the constant in equations 4 and 5 has to be increased. Values may be assumed for motors with characteristic torque curves similar to those of Figure 9 as follows:

For curve A—Total loss during acceleration will be approximately

$.00055 \times WR^2 \times (RPM)^2$ watt-seconds .....(6)

For curve B—Total loss will be approximately

$.00043 \times WR^2 \times (RPM)^2$ watt-seconds .....(7)

For curve C—Total loss will be approximately

$.00035 \times WR^2 \times (RPM)^2$ watt-seconds .....(8)

Similarly for reversal, the total loss in the motor during the reversal period, if motor is plugged will be approximately

Curve (A)—$.0022 \times WR^2 \times (RPM)^2$ watt-seconds (9)

Curve (B)—$.0017 \times WR^2 \times (RPM)^2$ watt-seconds (10)

Curve (C)—$.0014 \times WR^2 \times (RPM)^2$ watt-seconds (11)

It is to be understood that equations 6 to 11 are only approximate average values and are given to show the tendency rather than exact values. They could be used for preliminary calculations.

Now there are several very important facts indicated by the above equations.

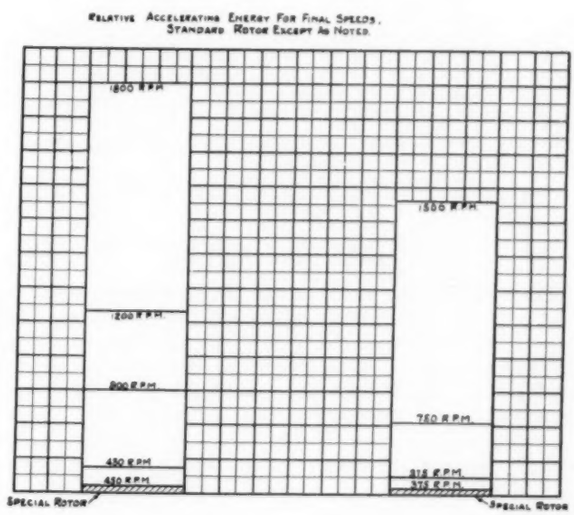


FIG. 13—Comparison of Energy of Acceleration for Various Final Speeds.

(1) The loss depends directly on the value of the total WR^2. Where the rotor WR^2 is a large part of the total it is therefore of prime importance to make the rotor WR^2 as low as possible.

(2) The loss depends directly on the square of the final speed and it is of the utmost importance, therefore, to keep this final speed as low as possible. For example, the accelerating or reversing loss for 750 r.p.m. is four times what it is for 375 r.p.m. provided the WR^2

remains unchanged. Similarly, 600 r.p.m. for equal WR^2's results in 180% of the loss for 450 r.p.m. speed. See Figure 13.

(3) The total loss is less for a motor having torque characteristics such as "B" and "C", Figure 9, than for "A" for the same values of WR^2 and speed.

(4) If the motor runs the most of the time, it will be an advantage to have it fan-cooled in order to get rid of the heat occasioned by the high reversing losses.

(5) If the accelerating or reversing losses are high and the motor only active during these periods, some method of cooling may be more economical than going to large motors which defeat the very purpose intended.

As an example of how the above data can be used, assume a cycle of accelerating, running, and period of rest. Let the accelerating period be 0.5 seconds, running 10 seconds, stopped 10 seconds. Load 10 h.p., WR^2 equals 20, RPM equals 870. Motor stopped by brake.

For motors over 5 h.p. assume a running loss of 140 watts per h.p. for Curve "B".

Accel. Loss $= .00043 \times 20 \times 870^2 =$ 6450 watt-seconds (equation 7)

Running Loss $= 1400 \times 10 =$ 14000 watt-seconds

Total Loss 20450 watt-seconds

The effective cooling time of a motor depends on its cycle of operations. If it runs continuously, then all the time is equally effective in cooling the motor and dissipating its loss. If it is stopped part of the time, evidently this stopped time is not as effective as the running time. A common method to find the effective running time is to take 75% of the accelerating, retarding, or reversing time; all of the actual running time; and 50% of the stopped time.

Effective running time = .75 x accel. time + actual running time + .5 x stopped time

$$= .375 + 10 + 5 = 15.375 \text{ seconds}$$

$$\text{Average loss} = \frac{20450}{15.375} = 1340 \text{ watts}$$

For a normal standard motor the efficiency of a 10 h.p. motor would be approvimately 89% so that the loss of 1340 watts would be that corresponding to a rating of almost 15 h.p. A 15 h.p. frame would therefore be used and the WR^2 of the rotor and connected parts would have to be within the value of 20 for which the calculations were made. The average value of the accelerating torque by equation (1) would have to be

$$T_a = \frac{20 \times 870}{308 \times .5} = 113 \text{ lbs. ft.}$$

If the load torque is present during acceleration it would have to be added. Load torque

$$= \frac{\text{B HP}}{\text{RPM}} \times 5250 = \frac{10}{870} \times 5250 = 60 \text{ lbs. ft.}$$

Total average torque necessary in motor during accelerating period would be 113 + 60 = 173 lbs. ft. In order to take care of contingencies such as cold bearings, extra friction, etc., and have a reasonable factor of safety, the starting torque of the motor would probably be 150% of the average given above or about 260 lbs. ft.

It will be noted that the accelerating energy loss is independent of the accelerating torque. This is true within practical limits. With a high torque the acceleration will be accomplished in a short time and the watts-loss large. The product of watts and time will be about the same as if the torque were low, the watts-loss low and the time long. Theoretically, it would be absolutely true for the rotor since the same energy is given to the mass irrespective of the time. Practically, it is not true for the whole motor due to differences produced by the magnetizing current, iron losses, etc.

Reversing cycles would be treated in a manner similar to the above using the equations corresponding to the case in hand.

As pointed out above, these equations are meant only to point the way and give you an idea of the nature of the problems involved. When a motor is designed, its losses can be determined for any cycle whatever with accuracy. The greatest difficulty generally arises from a lack of sufficient data or from incorrect or indeterminable data. It is highly desirable, therefore, from the standpoint of the motor designer, that all possible data be given on any problems of this nature.

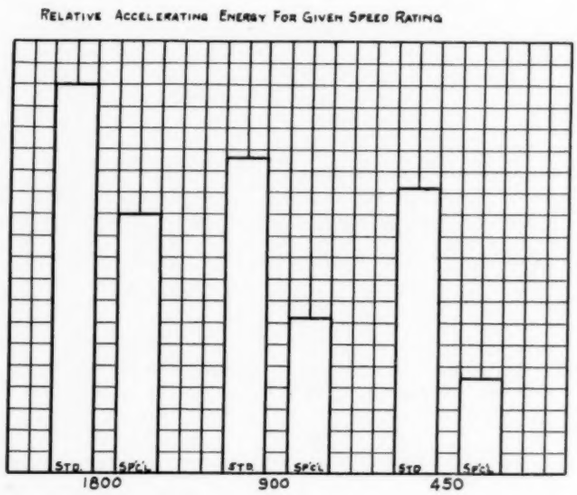


FIG. 14—Comparison of Acceleration Energy of Standard vs. Special Rotors for Various Speeds.

This paper is already longer than I anticipated but I would like to add a word on the stopping of squirrel-cage motors. This may be done mechanically by brake or friction. Electrically, there are two methods, viz, (1) plugging and (2) d.c. or dynamic braking.

Plugging is more strictly speaking, reversing rather than braking. The loss of plugging to a stop is three times that of accelerating as shown in equation 3 where $S_1 = 2$ and $S_2 = 1$. Not only is the loss high but manual attention or extra control must be used since if the motor is to be brought to standstill the power must be removed or the motor will be reversed.

D.C. braking is very desirable under certain conditions. With a d.c. current in the stator windings, a definite braking action is produced and the motor comes to a dead stop.

The braking effect can be graduated so that for example, for run-out table applications the time of braking can be adjusted to suit the material to be handled. Where plugging might scratch the material, d.c. braking can be made to give as gradual a stop as necessary.

In the case of run-out table motors, the use of d.c. braking can effect substantial economies. The heating of the a.c. motor is reduced and sometimes a smaller frame made possible. There are no rheostatic losses, the plugging d.c. generator having a voltage rating to suit the application. This plugging generator has an intermittent rating and is usually mounted as part of the M.G. set which supplies variable frequency to the run-out table motors. No extra wiring is necessary and only one additional contactor.

D.C. braking is not advisable for individual motors as it is uneconomical both in power and control. It is, however, particularly economical in cases as cited above.

We have seen that the squirrel-cage motor is much broader in its applications than those for which we are wont to give it credit and in the last few years particularly, have come many new and varied uses for this machine. In closing, I would like to point out that it would appear now that instead of being a motor of limited applications, the squirrel-cage motor is one to be more universally employed and one that will, in the next few years, show considerable increase in exceptional applications.

▲

Developments In Electric Motors and Magnetic Controllers To Handle Mechanical Processes In Sheet and Tin Mills

▲

By G. A. CALDWELL
General Engineer, Westinghouse Electric and Mfg. Co., East Pittsburgh, Pa.

Presented before Spring Conference, Combustion Engineering Division of the Association of Iron and Steel Electrical Engineers at Youngstown, O., March, 1932.

In presenting a paper describing some new development in electric motors and control, the subject is one that while very interesting is often limited in its application and which most of the steel mill engineers will never come in direct contact. However, this subject deals with equipment which has already been purchased by several sheet mills and in which many more mills are interested at the present time. Therefore, steel mill engineers are interested in this equipment not only because it is something new but as equipment which they will have in operation in their own plant. This paper has been written with the idea of answering the questions that most often have been asked in discussing this equipment.

Many improvements have been made in sheet and tin mill equipment in the last few years, and one of the most outstanding has been the development of the tilting tables and the automatic operation of them. These tables are the heart of the Combination System and Combination Method of rolling sheets and tin plate.

Just as it has been difficult to design a satisfactory table from a mechanical standpoint, so there have been many problems to solve to produce satisfactory electrical equipment. The development of the tables has passed through several stages and as finally evolved requires two motors for each table, one to raise and lower the table and the other to drive the chains. The function of the chains and the raising and lowering of the tables has already been described and need not be further discussed here.

The sequence of operation demands that the motors driving the chains be capable of frequent and rapid reversal. While the figure of 40 reversals per minute often has been mentioned as the rate of reversal of the chain motors, actual operation in the mill does not require over 20 to 25 reversals per minute. Even this figure represents very severe service with a reversal occurring approximately every 3 seconds.

The tilt motion is driven by a non-reversing motor through a gear reduction and a crank. The tilt motor starts and stops each time the chain motor reverses.

The mechanical design has been so balanced that practically the same torque is required for both the chain and tilt motors. Since plugging service is much more severe than starting and stopping service, the chain motors run hotter than the tilt motors. Therefore when a satisfactory motor is developed for driving the chains, the motor automatically becomes suitable for the tilt motion and so the advantage of using duplicate motors is possible.

On a drive where rapid reversing service is required, the work done by the motor may be divided into two parts, the work to drive the load at constant speed and the work done in accelerating and decelerating the moving parts. The only work done by the motor when running at constant speed is to carry the comparatively light pack of sheets and overcome the friction of the drive. An analysis of

the drive indicates that practically all the work done is in accelerating and decelerating the moving parts. A further analysis shows that that in the chain drive, there is very little inertia compared to the usual reversing application. The only parts driven by the chain motor are the chains, sprockets, gear unit, couplings and the motor rotor. When the WR^2 effect of these various items has been determined, a decision must be made as to the best motor speed to use. When the majority of the WR^2 effect of a drive is contained in the motor rotor itself, it is desirable to use a low speed motor. The stored energy in a rotating system is as follows:

$$\text{H.P. Sec.} = \frac{WR^2 \times \text{R.P.M.}^2}{3{,}226{,}000}$$

This formula indicates that the stored energy in the system is directly proportional to the WR^2 effect of the drive and proportional to the square of the speed which the motor attains. To drive a given load, changing the gear ratio of the drive to accommodate a slower speed motor means that the torque of the motor must be increased directly as the speed is decreased. Therefore if the WR^2 effect of the motor increases in about the same proportion as the torque of the motor is increased, the stored energy of the rotating parts will be nearly proportional to the speed of the motor. From these facts, it is evident that the motor should be as slow in speed as is practical to build. The motor frame necessary to produce the torque required for this drive does not lend itself to an economical design with a winding in excess of 16 poles. Therefore these motors are usually built with 16 poles for 60 cycle operation giving a 450 RPM. synchronous speed. For 25 cycle operation the motors are usually built with 8 poles giving a synchronous speed of 375 RPM.

With the motor speed determined, the next step is to calculate the torque required to give the desired rate of acceleration and deceleration. Since speed of operation is very important, as rapid a rate as practical is desired. On this application, the rate of acceleration and deceleration is determined by the slippage between the sheets and the chains. This rate of acceleration and deceleration must be determined by tests and experience. With the rate of acceleration and deceleration determined, the time for the motor to accelerate to full speed is easily obtained.

With the WR^2 of the various moving parts calculated and expressed in terms of the WR^2 at the motor shaft, the amount of average torque required to accelerate the drive in the desired time can be calculated from the formula.

$$\text{Time} = \frac{WR^2 \times \text{R.P.M.}}{307.6 \times \text{time}}$$

This gives the torque required for acceleration and deceleration only and by adding the torque for driving the chains at constant speed, the total accelerating torque is obtained.

It is evident from the above formula that for a given time to decelerate or accelerate, the torque required is directly proportional to the WR^2. Therefore the first requirement for the motor is that its rotor have the lowest practical value of WR^2 for the torque it must produce. As an example of what has been done in this respect, the standard rotor of the frame which is used for these motors has a WR^2 about four times as large as the rotor actually used for this application. The motor heating is also directly proportional to the WR^2 effect of the drive, since the work done in acceleration and decelerating the moving parts appears as heat in the motor rotor. In other words, if a motor is capable of reversing 40 times per minute without overheating with a given value of WR^2 to accelerate and decelerate, it will be able to reverse only 20 times per minute if the WR^2 of the drive is doubled. This statement neglects the friction and no load losses of the drive.

After factors such as speed and WR^2 have been determined, the motor must be designed so as to

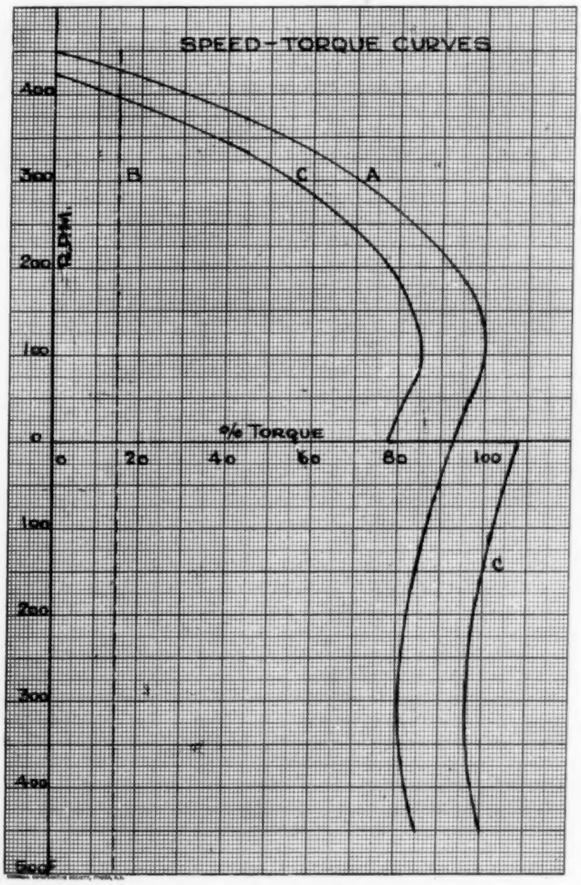


FIG. 1.

produce the most desirable speed torque curve and to have just as low losses as possible. The ideal speed torque curve is one that would give the same torque at all speeds from full speed plugging to nearly synchronous speed. The curve that has actually been produced for this application is shown as Curve A Fig. 1. With this characteristic, the motor develops its maximum torque at approximately 150 RPM. The torque developed by the motor at any speed lower than 150 RPM. and at any speed plugging is nearly equal to this maximum torque of the motor.

In this application, in calculating the accelerating times, the friction of the drive must be considered.

Oscillograph tests have shown that the friction torque is about 15% of the maximum torque of the motor and is represented in Fig. 1 by the line B. In accelerating the load, the torque available for acceleration is equal to the motor torque minus the friction torque while in deceleration the total torque is equal to the motor torque plus the friction torque. This net value of torque available for acceleration and deceleration is indicated by line C Fig. 1. These curves indicate that the average torque for deceleration is considerably higher than for acceleration and the decelerating time is therefore shorter than the accelerating time.

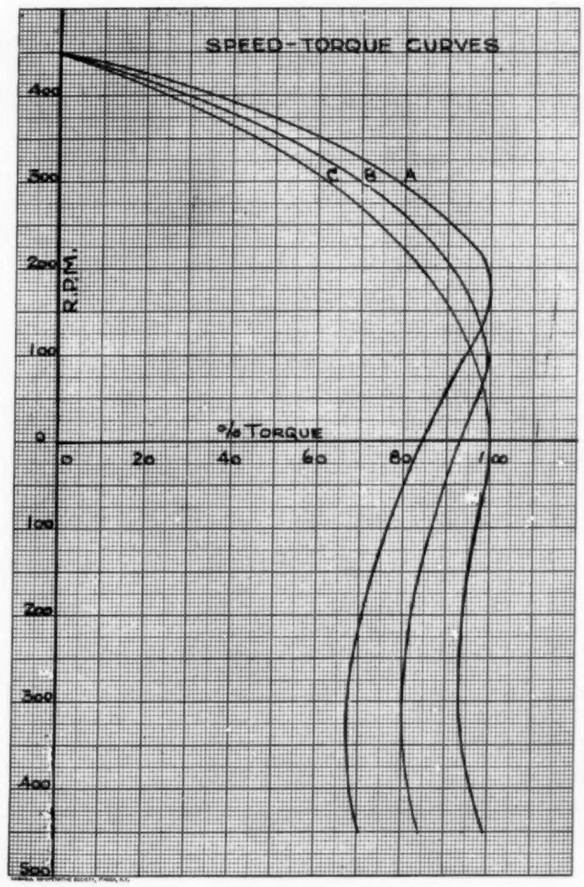


FIG. 2.

In Fig. 2, curve B is the same as curve A in Fig. 1. Two other characteristic curves A and C have been drawn, curve A being the characteristic of a motor with a smaller amount of secondary resistance than curve B and curve C being the characteristic of a motor with a secondary resistance greater than curve B. A characteristic such as curve A would make the accelerating time and decelerating time more nearly equal but the motor would have higher plugging currents with resulting higher motor losses. A characteristic such as C would give lower plugging currents than characteristic A but its average accelerating torque would be low and result in slower acceleration. Therefore, characteristic B is a desirable compromise between good acceleration and deceleration and low starting current.

Regardless of the final design, the losses in the motor will be high due to the rapid and frequent reversal and the motor must be able to dissipate these losses. On some tables used in sheet mills, totally enclosed motors are doing the work at a very satisfactory operating temperature. However in more severe service such as in tin mills where the sheets handled are shorter in length making the reversals more frequent and on large tables for sheet mills where the WR^2 of the drive is considerably increased, it has been found necessary to make the motor of the fan cooled construction. Although the fan adds slightly to the WR^2 of the rotor, the added ventilation lowers the operating temperature several degrees. The fan is made of a strong and light alloy and as a result adds very little to the WR^2 of the rotor.

The motor has several other features such as Class B insulation, roller bearings, and chrome nickel steel shaft to insure that the very best motor is obtained for the service.

While discussing motor characteristics we have always referred to A.C. motors. In the past, it has been considered necessary to use D.C. motors on rapid reversing applications. In this particular application trial of both kinds of motors have demonstrated the A.C. motors to be more suitable. Some of the advantages of the A.C. motor are as follows:

In the first place, there has been remarkable improvements in the design of A.C. squirrel cage motors in the last few years which have made it possible to get characteristics suited to rapidly reversing service. Improvement in rotor design makes it possible to materially reduce the WR^2 of the rotor for a given motor diameter and as a result practically the same torque can be obtained from an A.C. motor with a given WR^2 as can be obtained from a mill type D.C. motor.

The rotor of an A.C. squirrel cage motor is a very simple piece of apparatus compared to the armature of a D.C. motor. The rotor is of die cast construction and is practically indestructible. The problem of the proper insulation to withstand heating and avoid short circuit and ground, the maintenance of a commutator, brushes and brush rigging are entirely eliminated with the squirrel cage induction motor.

The control equipment for reversing an A.C. squirrel cage motor is very simple compared to the control equipment required to reverse a D.C. motor.

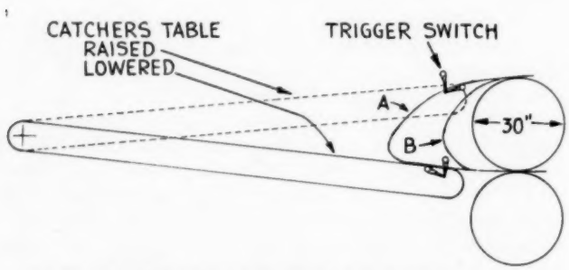
Due to the greater simplicity of the motor and control, the first cost of the A.C. equipment is considerably less than that of the D.C. equipment.

One disadvantage of the A.C. motor is that all the losses of the reversal must be absorbed in the motor rotor, while with a D.C. motor a part of these losses are absorbed in an external resistor.

The motors used in this application naturally have a low power factor and if many of the equipments are purchased, some form of power factor correction is desirable especially if power is purchased under a rate with a power factor clause.

The development of suitable control equipment had as its first requirement contactors and relays that would give several million operations without appreciable maintenance. When D.C. motors were

first used on these tables, suitable D.C. contactors were available for the service. When A.C. motors were used later, the D.C. contactors were still retained since they were more rugged than any A.C. contactor available. The current carrying parts of the contactors were suitable for carrying the A.C. current but it was still necessary to use D.C. power on the contactor coils themselves. Later as the control systems of the tables developed, one of the schemes of control demanded that the motors be reversed just as quickly as possible and the time lag of the opening and closing of the contactors was objectionable. Since A.C. contactors are faster in operation than D.C. operated contactors, some of the more recent installations have used the A.C. contactors with considerable success although the A.C. contactors are not considered to be as good for the hard service as the D.C. operated contactors. The A.C. contactor is inherently harder to design and build due to the laminated magnet construction and the tendency for the contactors to slam on closing.



PATH OF TRAVEL OF END OF SHEET

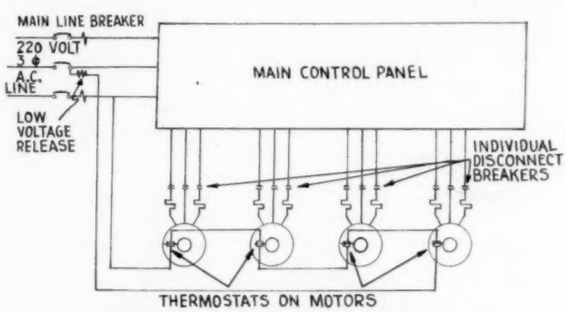
FIG. 3.

Consequently more maintenance is to be expected from this contactor.

Two different schemes of control have been developed to accomplish the same sequence of operation, the major difference being that one uses a trigger switch on the catchers tables only and the other scheme uses a trigger switch on both the catchers table and the feeders table. The sequence of operation of the table has already been described and will not be repeated here only as necessary to indicate the difference in operation of the two systems of control.

When a single trigger switch is used, as the sheet feeds through the mill and onto the catchers table, the trigger switch is depressed and as the sheet passes off the trigger switch, the control sequence is set up to reverse the chain motor and start the tilt motors of both tables to raise. As the sheet comes back towards the feeders side of the mill, the trigger switch is again depressed and as it passes off the catchers table the trigger switch is released and the control sequence is set up to start the catchers table in the down position. When the table approaches the down position, circuits are completed in a cam type limit switch on the catchers table which starts the feeders table in the down position. As the table starts in the down position a circuit is completed through the cam type limit switch on this table which again reverses the chain motor. The time delay obtained through the lowering of the tables is sufficient to allow the sheet to reach the feeders table before the chains reverse.

When two trigger switches are used, the operation is as follows: As the sheet is fed through the mill, the trigger switch on the catchers table is held depressed. As the sheet leaves the catchers table, the trigger switch is released and a timing relay is de-energized. After an adjustable time delay sufficient for the steel to pass through the mill, the relay operates and the control starts the tilt motor to raise and the chain motor reverses. At this time, the trigger switch on the catchers table is depressed and as the chain on the catchers table reverses, the sheet is carried back to the feeders table. When the sheet leaves the catchers table, the trigger switch on that table is released and de-energizes a time relay and after an adjustable time delay to allow the



METHOD OF MOTOR PROTECTION

FIG. 4.

sheet to reach the feeders table, the relay operates and lowers the table and reverses the chains and the cycle is automatically repeated. The advantage of the first scheme is that it is simpler and less equipment is required.

There are several advantages of the second scheme of control. The first is that it enables the reversal of the sheet to be started sooner on the catchers side of the table and thus makes the time of a complete cycle shorter. The path of the end of the sheet on the catchers side of the table with the two different schemes of control is shown in Fig. 3. Curve A represents the path followed by the sheet when the single trigger switch is used and path B is the one followed by the end of the sheet when two trigger switches are used.

A second reason is that since the reversals can be started just as soon as desired, the deceleration and acceleration of the chain motors can be made at a lower rate since it normally takes more time to raise the tables than to reverse the chains. The advantage of the lower deceleration and acceleration is that it avoids slippage of the sheets on the chain and in loose rolling avoids the slipping of the sheets themselves in relation to each other. Experience has shown that with loose rolling it is necessary to insert a step of primary resistance in the chain motor with the single trigger switch method of operation which of course slows up the cycle of operation. Since the deceleration rate can be lower, the service on the motor is not as severe and the motor torque can be smaller.

A point that has been given considerable atten-

tion is the overload protection of the motors. It is evident that when the load on the motor is constantly varying from no load current to plugging current, no relay responding to motor current can accurately protect the motor from overheating.

In the final analysis, the thing that must be accomplished is to keep the motor temperature below the point where the insulation will be damaged. Since the ambient temperature in the mill may vary over a very wide range from Winter to Summer, the motor current does not have a definite relation to the operating temperature of the motor. The simplest way of protecting the motor from overheating is to mount a thermostat directly on the core of the motor so that it responds to motor temperature. The thermostat is an extremely simple and reliable device which will trip when a temperature exceeding its setting is reached. The difficulty of duplicating the thermal characteristics of a motor in remotely situated apparatus is apparent and even a close approximation is almost impossible of commercial attainment.

The tripping of the thermostat may be used in two different ways according to the practice of the particular mill in which it is installed. It may either trip a main line circuit breaker disconnecting all four motors from the line or it may light an indicating lamp or ring a bell as a warning. This scheme of motor protection is illustrated in Fig. 4. It is also a desirable feature to be able to disconnect each motor from the line and for this purpose a small disconnecting switch can be used. The switch can also take the form of a circuit breaker and disconnect the motor in case of short circuits or stalling of the motor.

With this scheme of protection as indicated in Fig. 4 complete motor protection is afforded. The main line breaker gives disconnect protection and short circuit protection for the entire equipment. The individual breakers offer disconnect protection for each motor and also protect it from a stalled condition or short circuit. The thermostat on the motor protects it from overheating on duty cycle operation due to such conditions as excessive friction in the drive.

Since this equipment must be operated by men who are not accustomed to electrical equipment, it is important to make the operation as simple as possible. The sheet mill roller devotes most of his attention to the rolls of the mill and producing sheets that are straight, of the proper gauge and ones that do not stick together. Therefore, the control of the tables has been designed so that the operation soon becomes quite natural to him and does not require his attention to operate. With this idea in mind, a control station called a "joy stick" has been developed which has the complete normal control operation from a single handle. The handle can be moved to either the right or left, forward or back. Moving the handle to the right moves the chains to the right and moving the handle to the left moves the chains towards the left. Moving the handle straight forward puts the tables into automatic operation and moving the handle back operates an air valve which opens the side guards and raises a stop on the feeders table. When the handle is moved back it can still be moved to either the right or left and so operate the chains with the side guards opened and the stop raised. The operation has already been described and need not be repeated here. It is evident that this scheme of control is very simple and the operators become accustomed to operating it quickly.

You will note that the joy stick handle itself gives no definite control of the elevator motion except to give the automatic operation and the tables always stop in the down direction. Occasionally it is desirable to have manual control of the tables and for this purpose a switch is mounted on the joy stick to raise or lower the tables manually as desired. It is also desirable to have an emergency stop button to stop the equipment at any portion of its cycle. For this purpose a second switch is mounted on the joy stick complete with a reset contact for resetting the low voltage relay after an emergency stop.

The only other control equipment required besides the magnetic panel on which are mounted all the contactors and auxiliary relays consists of a cam type limit switch which automatically stops the tables in both their up and down positions, the trigger switches which control the automatic operation of the table, and a magnetic brake on each tilt motor. The cam type limit switch is of the normal cam type construction enclosed in a dust tight case. The trigger switches are of special design and built by the manufacturers of the tables.

The magnetic brakes are especially designed for the service, with cast steel parts and hardened pins. The coils are designed for quick setting and release and heavily braced to withstand the shock of the frequent operation.

A scheme of control has been developed to a point where the sequence of operation and interlocking is very simple requiring the minimum number of contactors and auxiliary relays. However, due to the large number of operations that the control equipment must make, it is important that this equipment be as rugged as possible. It is also necessary to have close co-operation between the design of the motors and the design of the control to produce the most satisfactory operating unit.

There is no doubt but what the development of the automatic tables has set a new standard for A.C. reversing motors and the necessary control equipment.

THE IRON AND STEEL EXPOSITION

▲

The Engineers and Executives of the Iron and Steel and Allied Industries are invited to attend the Convention and Iron and Steel Exposition of the Association of Iron and Steel Electrical Engineers. The Technical Sessions and the Exposition will be held at the William Penn Hotel, Pittsburgh, Pa., June 20th to 23rd.

Admission to the Exposition will be by ticket only and tickets may be secured gratis by writing the Association headquarters at Pittsburgh, Pa., or from representatives of the various exhibitors.

Motors and Control For Automatic Sheet Catchers

By W. B. SNYDER
Industrial Engineering Dept., General Electric Company, Schenectady, N. Y.

Presented before Spring Conference, Combustion Engineering Division, of the Association of Iron and Steel Electrical Engineers at Youngstown, O., March, 1932.

The automatic catchers which have been described in the previous papers impose rather severe requirements on the operating motors and control. The motor specifications call for machines which will reverse from full speed to full speed in 0.5 seconds, and which will operate continuously at the rate of 40 reversals per minute. The control equipment must, of course, also be designed for this severe operating cycle.

Most of the automatic catchers now installed are driven by squirrel cage induction motors. There are sound reasons for this; namely, that the electrical equipment for an A.C. drive is simpler and less expensive than for a D.C. drive, and that it operates from lower cost power. However, the D.C. mill type auxiliary motors now available will drive the catchers equally as well as the special A.C. motors do, so successful automatic catcher installations can be made in plants where A.C. is not available. Since the D.C. motors are well known, this paper will be devoted to A.C. motors and their control.

Motors to operate on fast reversing duty cycles, such as those obtaining on automatic catcher installations, must have the following features:

1. High average torque over the reversing cycle.
2. Low WR^2.
3. Efficient means of dissipating the heat generated in the motor.
4. Mechanical construction of sufficient strength to stand up under the reversing service.

All these factors are interrelated. For instance, the heat generated in the motor is largely dependent on the WR^2 of the motor and drive. Reducing the WR^2 reduces the heat to be dissipated, reduces the torque required to reverse the drive in a specified time, and reduces the strain on the mechanical parts of the motor. However, there is an economic limit below which the WR^2 should not be reduced. For example, the motor WR^2 may be reduced by reducing the rotor diameter. But reduction in rotor diameter means less room for the windings in the stator, and soon a point is reached where the reduced heating, due to lowered WR^2, is compensated by increased heating due to increased stator resistance. Also, the catcher motors are fan cooled, and an appreciable part of the WR^2 is in the fan itself. This can be somewhat reduced, but if the reduction is carried too far the fan may fail under reversing service. Thus a well designed motor is one in which all features are properly correlated, and not one in which one feature is emphasized at the expense of the others.

The motors for driving the sheet catchers are designed to provide the features mentioned above. They have high resistance rotors to give high average torque and to reduce motor heating over the reversing cycle. The WR^2 has been reduced by using rotor punchings much smaller in diameter than those of standard motors in the same frame, and by removing as much excess metal as possible for the punchings. They are provided with fans to assist in the dissipation of heat, and the motors are mechanically rugged. For example, the fans used on General Electric catcher motors are of aluminum and are cast on steel hubs which have deep radial slots to insure a strong bond between fan and hub.

Fig. 1 is a disassembled view of a totally enclosed fan cooled motor of the same construction as used for the catcher motors, and shows the heavy frame and end bells, the cartridge type ball bearing, and the rugged fans used on these motors.

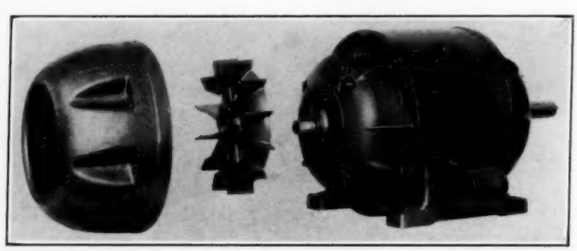


FIG. 1—Type of Construction Used for Automatic Catcher Motors.

The effectiveness of the fans in cooling these motors is, of course, due to the fact that even on a cycle of 40 reversals per minute the motors are running at full speed more than two-thirds of the time, as each reversal takes somewhat less than half a second.

The motors driving the tilting motions of the catchers have usually been made duplicate of the motors driving the conveyors. This has been done only for the purpose of interchangeability, as the duty on the tilting motors is much less severe than on the conveyor motors.

The insulation used in the motors for catcher drives conforms to A. I. E. E. Class B, and consists primarily of asbestos and mica. This insulation has two advantages. First, it permits the motor to operate at 75 deg. C. rise rather than 55 deg., and thus enables the size and WR^2 of the motor to be reduced. Second, this insulation has a very high safety margin above the established 75 deg. C. rise. As an instance of this, our company some time ago conducted tests to determine the effect of short time annealing on the cores of small induction motors. A motor was wound with Class B insulation and tested, and then the wound stator was placed in an annealing furnace. The stator was raised to the desired temperature, held there for a few minutes,

slowly cooled, and tested again. Three such tests were made at different temperatures, the highest being 1380 deg. F. At the completion of these tests the insulation was still good enough to permit running the motor for test purposes.

The method used in determining the proper induction motor for operation on a reversing cycle such as a catcher drive may be of interest. First, the application engineer needs to know the characteristics of the load; that is, the WR^2, the friction load, the time cycle, and the desired free running speed. With these factors known the selection of the proper motor becomes, not guess work, but a result accurately determined by calculation.

With the load characteristics known, the next step is to assume a motor and see if it will do the job. The selection of the "trial motor" is largely a matter of judgment, but a fairly close check on the selection can quickly be made. The average torque developed by the motor over the accelerating cycle, the friction load, and the combined WR^2 of motor and load will approximately determine the time of reversal. If the motor is too slow we reduce the motor WR^2, increase its torque if possible, or try

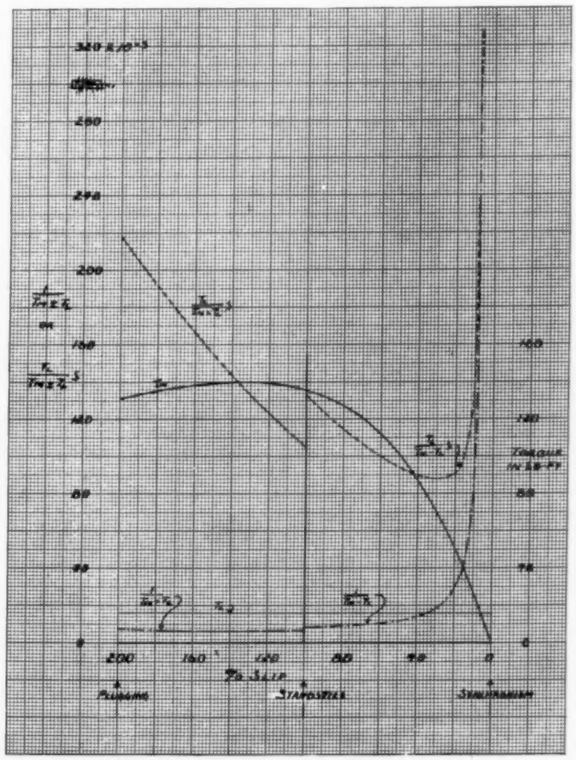


FIG. 2—Graphic Calculation of Performance of an Induction Motor on a Reversing Cycle.

a larger motor. If the motor is fast enough, heat dissipation is roughly checked. On a reversing cycle the heat developed in the rotor of an induction motor for each reversal is equal to four times the stored energy in motor and drive at full speed. This, plus the primary core and copper losses, and the losses at full speed, gives the heat generated in the motor, and, knowing the time cycle, the average rate of heat generated is readily determined.

Since we know the heat our "trial motor" will dissipate on the specified cycle, we also know if it appears big enough for the job. If the generated heat is more than the motor can dissipate, then we must adopt more effective means of cooling, say by selecting a fan cooled motor rather than a totally enclosed motor, or select a larger motor. Or, we may reduce the WR^2 of the motor, if practical, and see how this reduces the heating.

If our "trial motor" passes these preliminary tests, then a detailed calculation of its performance on the duty cycle is made. This can be done by a laborious step-by-step calculation, or more easily and accurately by graphic methods. A graphic calculation is illustrated in Fig. 2. On the sketch T_M is the speed-torque curve of the motor from the plugging point to synchronous speed. T_L is the friction load of the drive, which is assumed constant regardless of speed. The curves marked $\frac{1}{T_M+T_L}$ and $\frac{1}{T_M-T_L}$ appear rather meaningless, but it can be demonstrated mathematically that the average height of the curves multiplied by a few constants gives respectively the time required to decelerate to rest, and to accelerate to full speed. The curves marked $\frac{T_L}{T_M+T_L}S$ and $\frac{T_L}{T_M-T_L}S$ also appear meaningless, but the average heights of these curves, are representative of the effect of the

FIG. 3—Oscillograph Record of Reversal of Automatic Catcher Installation.

friction load in decreasing the rotor heating during deceleration, and increasing it during acceleration. To the heat due to the friction load are added the losses due to WR^2, the stator core and copper losses, and the losses during the free running period of the cycle. The total of these gives the amount of heat to be dissipated. We now know definitely whether or not the motor we have chosen will meet the duty cycle, both as to time of operation and as to heating. If the motor will not do the job, we select another one, and try again.

All this may seem a rather involved procedure, but it must be remembered that even if several calculations are made before arriving at a suitable motor, the only loss is a few sheets of paper and a few hours of work. If, on the other hand, a motor is applied without checking its performance as closely as possible by calculation, there is al-

ways the chance that it will fail in service and have to be replaced.

The performance of the first motors which our company furnished for catcher drives was determined by calculation before the motors were built. When these motors were put into service oscillograph tests were made to determine how closely performance checked the calculation. Figure 3 shows a section of a record taken with the catcher in operation, and it will be observed that both rollers' and catchers' conveyors reverse from full speed to full speed in somewhat less than 0.5 seconds. It should be noted that on this record the "speed" curves are of no value, due to misalignment and consequent vibration of the tachometers. Therefore, the time when the motors reached full speed is determined by locating the point where the current input is reduced to the free running value.

This catcher installation handles long packs, and thus will probably never obtain 40 reversals per minute, so unfortunately no field tests to check heating are possible. However, one of the motors was set up on the factory test floor, with a flywheel and a brake equivalent to the WR^2+friction of the drive, and a heat run was made with the motor reversing 40 times a minute. This test checked the calculation very closely.

CONTROL

While the control equipment for an automatic catcher requires rather complicated interlocking, it is made up of standard devices, with certain modifications to increase the life of the contactors and the tilting motor brakes on the severe service. Some users specify that the control for their automatic catchers be operated from D.C. power, feeling that D.C. operated contactors and brakes will have a longer and more trouble-free life than equivalent A.C. devices. While this feeling is probably justified by past experience, it is possible by slight modifications to provide A.C. operated contactors and brakes which will have an operating life equivalent to that of D.C. devices.

Aside from the wear of the tips, which is of course not a function of the current used in the operating coil, the first part of an A.C. contactor to wear out is probably the magnetic structure. On each closure the armature strikes the pole face with a hammer blow, and this continual pounding wears away the contact surfaces. The hammer action can be greatly reduced by designing the contactor coil for the actual range of operating voltage at the point of installation, and by shortening the travel of the armature. The standard specifications for contactor coils state that the coil shall be capable of closing the contactor with 85% normal voltage applied, and the manufacturers usually design these coils for about 80% voltage. The torque of a contactor varies as the square of the voltage, and thus at normal voltage the contactor develops over 50% excess pull which is dissipated in wear of the armature. On automatic catcher installations the voltage is liable to be above rather than below normal, because low voltage means less motor torque, and poor performance. Thus the life of the contactor can be greatly increased by the use of special coils rather than standard coils.

The addition of blowout coils permits the use of a very small gap between the stationary and the moving tips of a contactor, as, provided there is any gap at all, the blowout coil pulls the arc away from the contact surface up to the ends of the tip, and extinguishes it. Shortening the gap means less travel for the armature, which is accelerating all through the closing stroke, and thus less hammer action. However, the gaps of mechanically interlocked forward and reverse contactors can not be materially reduced because of the movement required to operate the interlock.

The expected life of an A.C. contactor with a coil designed for the actual operating voltage, and with blowout coils and a short gap, is of the order of 8,000,000 to 10,000,000 operations. The expected life of the mechanically interlocked forward and reverse contactors on the conveyor motors is about half of these figures, which means that all the contactors will wear out at about the same time, since each forward or reverse contactor operates only half as often as the tilting motor contactors.

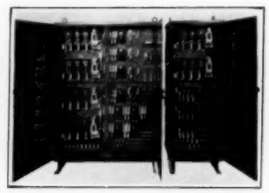


FIG. 4—Open View of Control Cabinet for Automatic Catcher.

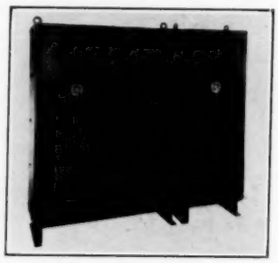


FIG. 5—Closed View of Control Cabinet for Automatic Catcher.

These values of expected life do not, of course, apply to contact tips which will probably have to be replaced after from 500,000 to 1,000,000 operations, depending on the current to be handled. Even if the magnetic structure of a contactor does require replacement, it can be removed from the panel and a new one installed without interferring with the other parts of the contactor.

A.C. solenoid brakes, like contactors, usually fail by pounding themselves to pieces, or the coils burn out due to overheating on frequent operation. The life of the brakes can be greatly increased by shortening the operating stroke, which reduces the hammer blow on releasing and which also cuts down the current inrush. Of course, shortening the stroke means that the brakes must be adjusted more frequently, but experience indicates that even with a shortened stroke the brakes do not need any more attention than that provided by the usual routine of mill inspection.

The use of A.C. control has some advantages. First, control power is supplied by the same line that supplies the motors, and thus operation is not contingent on the reliability of two sources of power.

Second, A.C. contactors and brakes are faster in operation than the equivalent D.C. devices, and this is of some importance where the equipment is laid out to save fractions of a second.

The control panels for automatic catchers are usually mounted in dust tight cabinets. Fig. 4 and Fig. 5 show open and closed views of two such cabinets furnished for a recent installation. The larger cabinet is a double furnace control unit. The four large contactors are for forward and reverse service on the furnace conveyors, and the upper four small contactors control door operators. The remaining contactors are relaying contactors used to provide the desired sequence of operation. The door operators are operated with electrically reset thermal overload relays which may be seen at the right of the door contactors. The timer which operates the furnace conveyors during charging may be seen at the upper right. This timer is driven by a Telechron synchronous motor and is designed for a 5-minute cycle. The percent time on is adjustable from 1% to 60% of the total length of the cycle by means of a dial inside the case.

The smaller cabinet houses the control for the blower motor, the return pack conveyor, the discharge conveyor, and for a cross traverse drive. The control for the tilting and conveyor motors is not shown, but is mounted in a cabinet similar to the larger one and presents about the same general appearance.

The cabinets are provided with doors on the back as well as on the front. These doors are each supported by three hinges and clamped shut by 3-point latches which wedge the doors tightly against wide felt gaskets. Thus the cabinets, while strictly dust tight, may readily be opened for inspection or repair of the control devices.

Discussion

H. M. Pier: The subject of fine gas cleaning has received considerable attention during the last two years. I want to take this opportunity of saying a few words about the installation, which we have recently finished, using the electrical precipitation method of cleaning blast furnace gas after the gas has passed through a primary scrubber. That is to say, the gas entering the Cottrell precipitator contains about .2 of a grain of dust per cu. ft. at 60° F. 30″ Hg. We are cleaning this gas to a dust concentration of .002 to .006 when treating from 15,000 to 25,000 cu. ft. of gas per min. in an installation, which was designed to handle 15,000 cu. ft. In other words, this unit is taking 60% overload.

The power consumption is about 5½ to 6 K.W. This is equivalent to about .4 of a kilowatt hour per 100,000 cu. ft. of gas.

This precipitator is of the tube type wherein the gas comes into the shell around the outside of the tubes and passes up through them. It is on the upward passage through the pipes that the dust is precipitated, and the clean gas passes out through the top. The tubes have a continuous overflow of water to carry off the deposited sludge as fast as it is precipitated on the pipes. The total water used for the removal of this sludge amounts to about 30 to 35 gallons per min. In addition to this continuous overflow, once in twelve hours for a period of ten minutes the volume of overflow water is increased to 250 gallons per min. This is for the purpose of removing any material that the continuous overflow does not carry off. This particular installation contains 120 tubes, each 8″ in diameter by 12 ft. in length.

The total cost of cleaning gas suitable for gas engines; that is .002 to .006, including power, water, steam, labor and in fact everything except fixed charges, such as interest, is about one and one-half cents per 100,000 cu. ft.

W. J. McGurty: Since our introduction of the mechanical scrubber to the primary cleaning of blast furnace gas, I feel that we have stimulated a widespread interest in getting this gas, cleaner than it ever was before this period.

As a matter of fact, due to arbitrary standards of cleanliness that are not based on actual experience, I also feel that money has been wasted in attempting to clean blast furnace gas to a greater degree than is necessary for many operations in which it is utilized.

With a recent development of our company, which is combined in one unit with our original primary cleaning system, we are securing a gas that leaves the scrubber slightly undersaturated at its temperature, thereby eliminating the entrainment problem and at the same time having a cleanliness satisfactory for its various utilizations.

These results are obtained with no increase in the power and water requirements or operating costs per ton, that were necessary for the original primary cleaning quality of one-tenth grain per cubic foot.

Many theories have been advanced as to what actually occurs in the cleaning of dust laden gases, which in my opinion are similar to the variable interpretations of the Bible that are the reason for so many different religious denominations.

B. W. Norton: We have had very little experience in cleaning gas beyond the Gas Washer stages. However, from the experiments conducted at the Youngstown Sheet and Tube on a small scale and from the data given in this discussion by the Chicago man it would seem that if electrical precipitation continues to give such results, particularly on a large scale that it will meet the requirements of the Blast Furnace Operators.

The gas according to the data ranges from .002 grains per cu. ft. to .006 which is clean enough for the small checkered stoves, for gas engines, for metallurgical uses and for heating at the coke ovens. The power costs are very low which is one or possibly the most important feature of this cleaning method.

G. T. Hollett: I have had some little experience with this new precipitator. The low pressure loss through this machine is noticeable. I don't remember if Mr. Pier mentioned that it is less than one inch loss of pressure through the machine, which is practically nothing. The fact that the machine will run continually without wear, repairs or plugging up is very commendable. This machine had run a

month or so when we took it off for inspection, and we found it in the same condition as when it went into service. It looks like it ought to continue to operate without any difficulty and no building up or wear, and at low power cost.

R. R. Harmon: The figures that I gave in the tabulation were that the apparatus handled from 3,000 to 3,500 cubic feet of gas per minute, measured at 60 degrees Fahrenheit and 30 inches barometer. The gas entered the washer at 250 to 300 degrees Fahrenheit. The outlet gas temperature was 70 to 80 degrees Fahrenheit. The incoming cooling water temperature was 60 to 70 degrees Fahrenheit, and from 16 to 28 gallons of water per thousand cubic feet of gas were required for cooling. The dust in the raw gas was about a grain and a half per cubic foot, and upward. More than 98 per cent passes through a 325 mesh screen, so it is very fine. The dust in the clean gas was 0.004 to 0.0087 per cubic foot. The average was 0.007. The horsepower for driving the scrubber, that is, the four sprayers, and for pumping the water to the primary and the secondary, amounted to 1.85 per thousand feet of gas per minute, which actually amounted to 2.3 kilowatt hours per one hundred thousand cubic feet of gas.

The primary contained four rotors, that is, four ordinary sprayers, which resembled a pan, with perforations in the rim. Recirculation was effected, as I explained, by returning the water, after it struck the shell, into the top of the sprayer. In that way the volume of water and density of spray created were independent of the quantity of water necessary to supply the primary from an outside source. That, of course, economizes the amount of water which goes through any settling or filtration system. Very little makeup water was added to the tank. We keep the cooling water separate from the water for the humidification process.

The condenser had six plates. The pressure loss was 8.5 inches of water column for both primary and secondary. In fact, keeping it that low was due largely to the design of the primary, where the gas had a spiral motion throughout the whole installation, there being no reverse turns and no baffles to restrict the flow. Consequently we get a great volume of gas through a given spray, under these conditions.

I might add, that one of the motivating reasons for this development work was to attempt to effect both primary and secondary cleaning in a single installation. If that could be done it would greatly reduce the cost of any cleaning installation, due to the fact that considerable piping and a number of goggle valves, and what not, would be eliminated. We have accomplished that purpose due to the fact that we have been able to control a natural phenomenon, which results in using the water vapor in the gas to the best advantage.

J. L. Miller: About six months ago we finished a complete Open Hearth Furnace campaign in which very extensive data was taken to determine the merit of compressed natural gas as an atomizing agent for By-product coal tar. As Mr. Emmerling has inferred in his paper our findings and results were not favorable.

This campaign was conducted in a manner to present a fair comparison between the subject methods of atomization; steam and compressed natural gas were employed during alternate weeks. Comparisons were based on averages for a large number of week day hot metal heats.

Gas atomizing required an average of 4% more total B.T.U. in fuel; however, because of the higher cost of natural gas heat units the gross fuel cost was 30% higher than with steam atomizing. Waste heat steam production increased almost in direct proportion to the increase in total fuel, although on a net fuel charge basis, after waste heat steam credit, the gas atomizing heats were 40% higher in fuel cost than with steam atomizing.

We were not successful in applying a burner with natural gas up to 150 lb. pressure that would atomize as effectively as with steam, nor could we get below about 35% of the total heat input in the form of natural gas. Some interesting results were obtained from the use of compressed air, preheated compressed natural gas and preheated compressed air as atomizing agents. No economic or apparently feasible substitute for steam atomizing however were indicated from these tests.

C. Emmerling: I don't believe I have a great deal more to say. Natural gas can be used in almost any heating application that comes up in a steel mill with the exception of a blast furnace, and of course there is no heat used in a Bessemer, but outside of that it can be used in any of the heating applications. The question of economics is, of course, the final answer. You must do the work for at least what it costs with the present fuel. Sometimes that is rather a hard job because right now fuels are quite cheap, and natural gas has not come down as much as some of the others.

H. H. Holloway: I would like to ask Mr. Wean and Mr. Melin in regard to the scrap percentages of the companies that are using the automatic feeders, if it compares favorably with the hand method.

Some two years ago we put in an installation of this continuous proposition at our place, and we put it in for the sole purpose of making auto body sheets. You people in the sheet business know exactly what happened about two years ago. We started in on a product that declined, and we were compelled to make light-gauge material on a furnace that was solely designed for making auto body sheets. We worked the proposition out and at the present time we are able to get an average for a year of about 19 tons per six-hour turn, with a scrap percentage for the entire year including re-square scrap and pickle loss, under 13¾ per cent on a production of approximately 55,000 tons.

I don't think that anybody, or any company, yet knows what the capacity of a sheet mill is. The other day we ran a test in our plant. We only have a 30-foot furnace and for one hour we went at the rate of 240 pair of 18x36x?? rolled by a roller and a catcher and delivered by hand out of a furnace, which would be at the rate of about 103,000 or 104,000 pounds for a six-hour period. If these furnaces can be equipped and our rolls can be made so that they will not pit, I don't think we have very much to worry about on the continuous strip mills.

We, as a company, are very well pleased with the results we have obtained, and at the present time we are putting in a mill to make from 28-gauge up. We don't know how far up and we don't know the capacity. We have tried some experiments in

our plant and we hope that we are going to make in the neighborhood of 25 tons of 30-gauge in a six-hour period.

C. J. Daley: Mr. Chairman, I didn't happen to be present this morning in time to hear Mr. Wean's paper, but I might say that we have two installations, one of the Surface Combustion type and one of the Wean type, both of which are comparatively new. We haven't had very much time to find out what we are going to do on them.

In answer to Mr. Holloway's question with reference to scrap, I might say that our scrap percentage is not quite as good as on the handmill, but there is a gradual reduction each week. We hope eventually to get our scrap down to where we have it on the hand system.

L. Larson: Our experience with the continuous furnaces, and separation of roughing and finishing, has now extended over a period about two years. Results obtained are substantially in accordance with the facts and claims brought out in these papers. Savings ranging from $1 to $6 per ton have been made on production of full finish sheets.

Reduction in cost varies with gauge, size and specifications of product, and is reflected largely in labor, and some in fuel, power and indirect items, due to concentration of equivalent tonnage on fewer producing units. Uniformity and quality of product have been improved.

Mention was made by Mr. Wean in his paper on desirability of furnace design that would permit use of more than one fuel. I question the possibility of designing any sheet heating furnace for a given fuel and later using another fuel with different characteristics, without suffering either in fuel economy, quality of heating, or both. The particular question in mind is whether a furnace designed for efficient use of natural gas could be utilized for efficiently and successfully using producer gas or oil, or vice versa.

Mr. Emmerling takes the position that irrespective of a higher cost per million B.T.U., natural gas offers the lowest cost per ton of product, in that other factors will more than compensate for the difference. This is a broad claim, and a natural one for Mr. Emmerling to make. The possibilities offered in lowering costs by use of other fuels, prompts me to seriously question this contention.

A Member: I wasn't privileged this morning to hear Mr. Wean's paper, nor any of the other papers. I did enjoy the papers this afternoon.

Our installations of the continuous furnaces are rather recent, and for us to draw any definite conclusions as to what we may expect on what we have done in the past would probably be just a little disappointing. We have had some trouble, the same as everybody else who installs them. As you know, it is a radical departure when you hand a man a street car controller and tell him to roll steel. He can drive his automobile but he has been used to having tongs when you talk to him about rolling pack sheet iron. I think there has been a very marked progress in the mechanical handling of sheets in the continuous furnace, but I would like to issue this little word of warning to the representatives of the furnace builders and the mechanical means for handling sheets. There are a great many fundamentals there that should be given a great deal of thought. Some people like their eggs straight up and others like them fried on both sides. Now there are the two furnaces, and personally there are a great many things in connection with the rolling of sheet iron that I believe many people do not, or did not, realize existed, and I believe these furnace manufacturers are beginning to realize it. We are not at all disappointed and we are living in hopes.

J. A. Hunter: I have enjoyed listening to these most interesting papers and I think we are all greatly indebted to the authors for coming here today and telling us about the latest developments of rolling by the various systems; also of the development of electric equipment for driving and controlling the operation of the tables and furnaces. The satisfactory results now being obtained have only been accomplished by the simultaneous development of both classes of equipment.

It is difficult, at this time, to state the ultimate results which can be obtained with this method of rolling. The equipment has not been in use long enough for the operator to become thoroughly familiar with it, and also as stated by Mr. Wean, improvements have been made continuously so that we have not approached results which are possible.

The equipment is now developed to such a point that I feel that very shortly surprising results in capacity and costs will be obtained.

R. J. Wean: Mr. Daley answered Mr. Holloway's question, and I can say substantially the same, that taking a cross-section of numerous installations the yield has not been quite as good as on the hand method. However, developments have been under way for some time that should make it possible to get as low a scrap, or even lower, than the old method of measuring with the rod, and that will be done without any sacrifice in production on the mill. In fact, it may be quite an aid in getting higher production because now some mills measure by marking the side guides, measuring it before the last pass, and in some other plants they bring it back over the mill just for measuring. In other mills they allow a little more scrap so they don't have to measure, and offset it with the extra tonnage. I have seen units where they didn't measure one out of fifty packs, and with good furnace conditions, good heating results, and good overall operation they get very close lengths due to the constant operation, no stopping at any point.

With regard to Mr. Larson's question on fuel, I think that that is an absolutely good statement, that the average furnace cannot be equipped for dual fuel purposes. That is especially true if it is a multiple burner furnace, in my opinion. I am stating an opinion. However, it is a fact in the radiant gap furnace, and we have, as I say, over 130 of them in operation. We have equipped numerous furnaces to fire either oil or gas, and we may use it on and off two or three times a week depending upon the availability of the gas. Definite checkups show that on the gas, natural gas or even coke oven gas, we get comparable results so far as fuel consumption is concerned with any other type of furnace, and of course on the oil it is at a considerably lower cost due to the low price of the oil at this time.

Now if you want to go to producer gas that is another subject. You can't, as far as I know, fire

natural gas today and producer gas tomorrow. However, you can take the same furnace and by changing the burners and making some slight brick changes in the combustion chambers, change it for a permanent producer gas installation. We did that at the Michigan Steel Company. We fired oil originally, and then when they changed their plant and went to a producer gas plant for the whole battery of furnaces we changed all of the original oil furnaces by simply changing the burner and some slight brick changes, to producer gas. As you know they roll nothing but full finished sheets, and probably the best of full finished requirements, with very good results.

There is one thing I would like to say in conclusion, that is that Mr. Daley is absolutely right. Sheet rolling is not so many pounds of steel, so thick and so wide. We have a multitude of finishes, a multitude of conditions to work under, surface requirements, later treatments to be considered. All those things must be considered when you roll it.

There is a lot of, what I call, horseback engineering going on by men telling the sheet man today what he should do. The sheet man should tell the man what he wants to do, but how many of them can you find who will absolutely set up the requirements? Too many statements are made based upon opinions, not facts. There have been opinions expressed in the last year or two that have been exploded a dozen times. There have been opinions expressed in here today that will be exploded the same way. You men are the men who are responsible for the specifications laid down on equipment. If you will lay down the results you want, and the men who are talking to you and trying to fill your requirements will stick to facts, known practice, you can get results that are way beyond anything ever conceived out of a sheet mill. It is going to mean co-operation and tearing away all of these beclouding discussions and issues before we get that very low cost, which I term the lowest ultimate cost, and it is going to be lower above the 20-gauge line than any other material that is being made today, and that goes for any finish.

R. O. Herbig: Mr. Melin made a statement this morning in his paper on the reduction in cost. He said that the old crew on the hand method consisted of nine men and the crew on the new method would consist of two men. I wonder if he will tell us just what each of those nine men did and what each of the two men is to do on the new setup.

H. Melin: I think it is known that in the old-fashioned mill, the so-called conventional mill, it requires a crew of nine or ten men, the roller and his helpers. In the paper that I read I stated not that two men were required in a mill running on the Combination Method, but a crew of five or six men. However, of these five or six men, there are only two, the operator and the operator's helper who have to be skilled and be paid accordingly. The others can be paid slightly above or at labor wage.

I will also say that the Combination Method in its present shape is not complete. As you notice, the Combination Method only takes care of the break-downs to finish them into hot rolled sheets. Our company has under development, as I mentioned, further mechanical improvements to produce the entire rolling mechanically, from bars to finished product.

J. H. Van Campen: Gentlemen, I believe what Mr. Melin says is true. The present day developments regarding this method of producing sheet and tin plates seem to be only half the picture. No doubt, one of these days someone will develop a perfect automatic bar feeder and catcher for roughing work.

Another thing we can't lose sight of in this arrangement of producing sheets is the time element. We have an installation in the Warren Plant of The Republic Steel Corporation for producing tin black plate. We are producing there an average of about 480 packs a turn. We do not feel that this is the limit. Taking the cycles on this operation, we find that in running at the rate of 480 packs a turn this is equal to 60 packs an hour or one a minute. Our actual effective producing time on that arrangement is about 37.5 seconds out of the minute. Various little features in the arrangement can be speeded up, possibly such as furnace discharge, higher speeds in carrying the pack from the furnace to the roller's feeder table, anticipating the delivery time of the pack from the furnace in relation to the last pass of the preceding pack into the mill, possibly by later going to larger diameter rolls on the mill. By speeding up these various features we hope that ultimately the operating time out of the minute will be around 42 to 47 seconds and by so doing, increase production to possibly 600 packs in a turn. So in this arrangement of equipment we cannot afford to lose sight of the fact that seconds and fractions of seconds count an awful lot.

If there are no further questions or discussions regarding these two papers, we will proceed to the discussion of the next paper.

F. E. Leahy: I am rather surprised that there is not a lot of questions on this subject, because I know every time I have been in any gathering where there have been sheet mill men involved at all this question of heating seemed to take precedence over any other subject.

I think this is a very important question, and as Mr. Wean remarked here a little while ago, there seems to be some doubt from questions raised about different factors; particularly by those who do not have any experience with the equipment. I believe the more of this equipment that is placed in operation, the quicker we will get to that point that many of you are discussing, of larger tonnages than the present practices make possible.

We all heard the description this morning of these two systems of making sheets. They have merit. They both must be properly applied to any particular mill to get the desired results.

There are features in the practice that have developed since the automatic mills have been installed in our plant that we are now working on. In adapting the hand practice to the automatic practice some very important factors in the operation, we believe, have been overlooked.

I think this question should be discussed thoroughly for the benefit of everybody. From our experiences I would say that proper heating is extremely important to the success of this operation.

J. A. Hunter: I do not have anything to add except I have been asked how the quality of material

produced with this method of rolling compares with that obtained from the old method. I wish to state that it is superior. The heating is more uniform and it is absolutely flat, all of which tends to give a better product both from a standpoint of surface and structure.

G. T. Hollett: When using these furnaces in heating the higher quality of steel, that is, your stainless steel and your alloy steels, there are some problems that come up that you do not find in the ordinary soft steels.

T. J. Ess: My remarks are entirely of an inquisitive nature. I would like to ask, first, for some relative capacities of furnaces that are fired by luminous flames as compared with non-luminous flames. Secondly, I would like to know just how far we are justified in going to incomplete combustion as a means to retard scale formation at the temperatures that prevail in pair and pack furnaces, and I would like also to hear some statements as to the relative life of the alloys entering into this furnace construction.

R. L. Corbett: With regard to luminous flame used in connection with a walking beam furnace, I might say that we have not had any experience along this line. One of our main reasons for being a little cautious on luminosity is due to the fact that we don't believe a walking beam furnace which conveys the material through in step by step progression is applicable to a luminous flame condition, due to the fact that the continual rising and lowering of the material upsets your stratification.

Another question that has been asked by Mr. Ess was the life of the alloy. In designing your alloy-carrying members it must be conservatively stressed. Quick time pull tests are of no value. What we are interested in is the life of the alloy over a reasonable period of time. Alloy castings must also be designed in reasonably short uniform sections, with provisions made for unit expansion and contraction. We have walking beam furnaces which have been in operation for the past three years. The design of these furnaces is very similar to the ones we are now offering to the sheet and tin mill trades. They are operated at temperatures of from 1650 to 1700 degrees, and are used for heating bumper stock and spring leaves before the quenching or hardening operation. From recent inspection of this alloy there are absolutely no signs of deterioration. From the looks of the alloy it appears that it will last almost indefinitely.

In closing I would like to recall a recent experience which we had in connection with the heating capacity of our furnaces. We were given a certain definite tonnage to turn out. It appeared to this particular mill that the furnace was not delivering the tonnage for which it was sold. The furnace, after checking into it very carefully, turned out more production, considerably greater production than it was sold for. Unfortunately they were using the old style hand system. This furnace in particular was used for pair heating. There were periods of time when this would be roughing pairs at a very rapid gait, and then naturally a shut down for possibly roll polishing and changing of crews.

The point that I would like to bring to your attention is that when you are figuring on a furnace or furnaces, always remember to take into consideration the mill shut-down periods. In other words, if I am driving from here to Cleveland I may be traveling 55 miles an hour most of the time, but my average speed would be 35 miles an hour. That is a point that a good many of you should take into consideration. That obviously will be eliminated, holdups and so forth, with the new Combination System and Combination Method.

A. L. Hollinger: There is considerable misunderstanding as to the adaptability of the luminous flame to heating furnaces. I can say that in our opinion luminous flame or diffusion combustion as such is not adapted to heating a pack furnace. We use, in combination with our premix system, a modification of diffusion combustion for conditioning the furnace atmosphere.

I want to confirm from our viewpoint what has been said about the life of alloy castings under these conditions of operation. The question that is asked whenever pack furnaces are under discussion is, How long will the alloys last? We don't know by reason of the fact that we haven't enough experience back of us. We do know that we have furnaces that have been in operation for three years and longer, and with the original beams. Our ideas as to the eventual life of alloys have certainly changed over the last three or four years, and we expect now that alloy castings properly designed and properly made should have an almost indefinite life.

I conclude this way, our pack furnaces are necessarily still in a stage of development by reason of the fact that the mill and the automatic equipment on one side can't say today what the final demand will be. Certainly we put furnaces in two or three years ago which, so far as capacity went at least, we said would never be met, yet those furnaces today are all too small. We are putting in furnaces today which are twice as big. We are putting in furnaces today with a much greater speed. We have increased the length of the stroke. If somebody would say to us, "This is the ultimate,"—we could say, "All right." This furnace will answer. In the meantime it is almost impossible for a mill to make an investment in a piece of equipment to anticipate 100 per cent overload until they find that the overload is there. The thing we can do is to build these furnaces and anticipate while we are building them just as much as we possible can those things that may eventually be demanded.

F. J. Burd: A number of years ago Mr. Friedlander, while at the Edgar Thomson Works, told me of his experience in the early days in the electrical department where the job was to make a control last one week. They were entirely satisfied to replace it at the end of the week. Nowadays we expect a control to last two years and in that time make about twenty million operations without any undue wear or replacements of parts. This simply indicates what has been done in the development of the control.

There is not very much I can add to what has been said on the development of the control for these pack furnace jobs because it would only be a repetition of what has gone before.

Back in 1926 I had the pleasure of working with the late Mr. McArthur developing a control for his catcher. In fact, it was the first successful control

for the McArthur table, and as far as I know they are still operating successfully.

I have one question I would like to get Mr. Wean's opinion on. How would the load be effected on the main drive of a number of stands? Say we have a drive on five stands, and it so happens we want to put automatic tables on each one of these stands. There will be more passes per minute, consequently a higher average load on the main drive, and a greater production. Would that mean that we must do something with that main drive to take care of this increased load?

A. M. MacCutcheon: The only comment that I have to make is on the electrical end, referring particularly to the motors and to Mr. Henderson's paper. The real credit for the application of A.C. motors to the feeder and catcher tables lies with Howard McIlvried, of the American Sheet and Tin Plate Company, who insisted that it should be possible to successfully reverse an A.C. squirrel cage motor 40 times a minute. With one exception, all designing engineers felt it was impossible to design such a motor and guarantee its performance. The exception was Mr. Henderson. He alone had the engineering vision to recognize the possibilities and the engineering courage to proceed. Two years later, with one and a half years of successful operation, all engineers are compelled to recognize that Mr. Henderson was right.

As a prominent engineer has said, "Nothing can replace experience," and particular emphasis should be placed upon Mr. Henderson's recommendations as to the proper balance between motor speed, torque, loss and heating. The successful A.C. drive of roller and catcher tables is an outstanding contribution to motor application in the steel mill and with 22 successful drives to his credit, Mr. Henderson should be recognized as the successful pioneer.

W. B. Shirk: Mr. Chairman, Mr. Caldwell stated the motors driving the tables have a low power factor during the starting period. This point should be kept in mind by every plant engineer due to the fact that the success which the sheet catcher has attained will naturally lead to a large number of installations of small squirrel cage type induction motors. Every engineer identified with power system problems is naturally interested in maintaining the most economical power factor on the system involved.

Due to the fact that the squirrel cage motors applied to these sheet catchers are primarily designed for starting duty only our engineers feel that they should apply the same ingenuity in designing these squirrel cage motors as they use in designing the damper bar winding of large main roll drive synchronous motors. Back in 1926 and 1927 we supplied synchronous motors that had a torque efficiency of approximately 25%. In 1929 we quoted synchronous motors with a torque efficiency of 45%. This means that you are obtaining approximately twice the starting torque for the same inrush KVA, due to the increased torque efficiency of the motor. Higher torque efficiencies also results in higher average power factor during the starting cycle from zero speed to the maximum free running speed.

One of the previous speakers stated that the question of slip should be taken into account when laying out the limit switch operation on the tables. I feel that if these sheet catchers are applied generally to sheet mills, we will have to eliminate the wound rotor induction motor and flywheels due to the fact that the load will be maintained so steadily that we will be required to use synchronous motors or wound rotor induction motors without flywheels.

From tests we have made on mills which only had one stand equipped with tables, we found that the slip developed by the load on the main drive motor did not handicap the limit switch operation. By means of suitable limit switches and proper adjustments we were able to make the end of the sheet follow the contour of the roll which is very desirable.

G. R. Carroll: I don't feel that I have anything to add to the papers read here today, but I think that the people who prepared them are to be congratulated. They were very interesting.

There is one question that occurs to me that somebody might be able to answer. To what extent does the cost of the power enter into the cost of the plate rolled in using this new method? In other words, is there any change in the KW. hours per ton.

J. J. Mellon: I agree with Mr. Wean's statement that operating men from the Sheet and Tin Mills should tell the Manufacturer the type of equipment that their particular plant requirements demand on these special applications, rather than the reverse.

In summary, I would like to say that there are available today, either A.C. or D.C. operated A.C. controllers with either A.C. or D.C. brakes for use on these Roller and Catcher Tables, without paying any appreciable penalty either in time of operation or in maintenance.

On the point brought up by Mr. Shirk as to whether one or two flag switches should be used, I feel that that is entirely a matter of opinion. It is my feeling that only one flag switch is necessary. Recently, I asked the Electrical Superintendent of a large sheet mill, who has had considerable experience with this equipment, how many flag switches he thought should be used on a Roller's and Catcher's Table. His reply was that any number could be used as long as it was less than one. If we can be positively sure when using one flag switch that it is impossible for table tilting to take place before the sheet is out of the main rolls and also clear of the rolls, and if we do not slow down operation by so doing, then the one flag switch method is the best for accomplishing this purpose. Many installations now operating show that the above conditions can be met with one flag switch.

G. A. Caldwell: Mr. Mellon's closing remarks are in accordance with my opinions on the operation of the tables. Most of my discussion was devoted to the scheme of control which uses a trigger switch on each table. This scheme has certain advantages which are desirable as I have already pointed out.

The most serious objection to the use of two trigger switches is that there is an additional switch to maintain. However it must be remembered that when two trigger switches are used, the trigger switch operating mechanism can be much larger and consequently more rugged and reliable. On present tables using two trigger switches, they are

giving very satisfactory service with practically no maintenance.

The main advantage of using two trigger switches is that the raising of the catcher's table can be started sooner and thus make the time of the cycle shorter and at the same time use a slower decelerating rate on the main motors.

Our company has built control equipment for both double trigger switch and single trigger switch operation and is willing to leave the choice entirely to the builder of the tables. We have also built the control with both A.C. and D.C. operated contactors and brakes and will supply either kind as desired. However it must be remembered that when two trigger switches are used the faster closing of the A.C. contactor is no longer an advantage.

E. W. Henderson: There were one or two questions which I will just touch on.

In regard to this question of power factor, when you realize that all of the energy spent during the time of operation is practically spent in reversing and in starting the motor, even though the power factor of the motor running may be low, yet under operating conditions I think you will find that the power factor will be relatively quite high. Then again I think the end justifies the means. A slip-ring motor we operate at low speeds for certain conditions. We know they are inefficient, yet we use them because they possibly do the job best. We use these squirrel cage motors the same way. As Mr. Caldwell said, they have many superior points when compared to the ordinary D.C. mill type motor. The control is much more simple, the cost is less, and so forth. So there are many things that are in favor of the squirrel cage motor even though the power factor may not be up to snuff.

In regard to power, I haven't any figures on power.

With regard to Mr. MacCutcheon's point, I wish he hadn't brought it up. He has placed me in a very embarrassing position. I am not going to be uppish because Mr. MacCutcheon paid me that compliment. This is not a day of single effort. No man accomplishes a thing by himself these days. Mr. McIlvried said, "For God's sake, Henderson, it isn't a matter of can you do it. You have got to do it." There, is the reason.

W. B. Snyder: I have nothing much to say in conclusion except, perhaps, to assure you for the third time that the manufacturers can furnish either A.C. or D.C. control for automatic catchers.

The capacity of the motors driving sheet and tin plate mills must be investigated if the mills are to be equipped with automatic catchers. Practically all of the present motor driven mills have heavy flywheels and are driven by slip-ring motors. On these drives the size of the motor is chiefly dependent on the average load. Experience shows that the KW-hours per ton consumed by the main motor do not change very materially between the old and the new methods, and thus if you are going to double your tonnage by the use of automatic catchers you are doubling the load on the motor.

I also agree with Mr. Shirk that, since the application of automatic catchers raises the average load on the mill without raising the peak load materially, there will be more and more synchronous motors used on sheet mills.

R. J. Wean: I think Mr. Snyder answered Mr. Carroll's question, although I think there are some men here who have had some definite experience along that line. I know that Mr. Hunter one time made some tests as to the extra demand on the main drive motors. My own personal impression is that your peak demand isn't any higher, but your average demand is much higher.

Discussion*

Discussed by

W. Anderson, Engineer, General Electric Company, Pittsburgh, Pa.

J. W. Bates, Electrical Engineer, American Sheet & Tin Plate Company, Pittsburgh, Pa.

D. I. Bohn, Electrical Engineer, Aluminum Company of America, Pittsburgh, Pa.

E. W. Henderson, Design Engineer, Reliance Electric & Engineering Company, Cleveland, Ohio.

J. I. Kaspari, Asst. Electrical Supt., Weirton Steel Company, Weirton, W. Va.

W. B. Shirk, Steel Mill Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

C. O. Franklin, Asst. Electrical Supt., Carnegie Steel Company, Homestead Works, Munhall, Pa.

W. Anderson: The paper we have heard this evening, most ably presented, is a very timely one, as the near future will undoubtedly see an increasing application of A.C. motors, both squirrel cage and slip ring, to mill auxiliary service. Such applications as automatic catchers, screwdowns on small continuous mills and runout tables, are becoming more and more fields for the A.C. motor. This is partly due to the ordinary development in A.C. design and also in no small degree to the initiative and persistence of you operating men in urging on the manufacturer the necessity for developments which he might otherwise be slow to recognize. It is by such co-operation that we can expect the earliest and fullest development of the possibilities of the A.C. motor, which is undoubtedly coming more and more into its own.

The D.C. mill motor still remains as supreme where extreme flexibility of control is desired. On a large number of start, stop or forward reverse cycles, however, the A.C. motor is quite suitable. Certain modifications of standard design must always be made to meet severe specialized requirements and sometimes the final product is quite different in appearance. The heavy duty wound rotor A.C. crane motor is all steel construction, except the windings, totally enclosed, and mechanically

*This discussion presented at A. I. & S. E. E., Pittsburgh District Section, March 19, 1932 when Mr. Henderson presented his paper "The Squirrel Cage Induction Motor as Applied to Starting, Reversing and Stopping Duty."

rugged enough for the most severe service. Such construction can, of course, be extended as the demand develops to the smaller motors.

Some applications impose more severe electrical and heating requirements than mechanical, and the speaker has pointed out how far this design, in the simple, rugged squirrel cage construction, has gone toward meeting the most severe demands.

In this particular application, due to the extremely high gear ratio immediately beyond the motor shaft, the mechanical service, aside from the necessity for frequent reversal, is not exceptionally severe. This requirement of frequent reversal necessitates the rugged rotor construction of course.

The disadvantages of the squirrel cage motor, as compared to the slip ring or the D.C. motor, are mainly two. In the first place the kinetic energy involved in plugging to rest or to full reverse appears as heat inside the motor, while in a slip ring motor or D.C., most of it is dissipated outside in resistance. Secondly, this external resistance, which is of course variable by suitable control, permits a variation in the motor characteristic, while a squirrel cage motor, with across-the-line operation, is more or less fixed as to characteristics, which must therefore be more carefully chosen for the job. Even on severe duty cycles, the conditions may be such as to get too much torque, too sudden acceleration.

On automatic sheet mill catchers, for instance, the motor, for certain classes of work, at least, must reverse the conveyor quickly, forty times per minute if necessary, but not slip the conveyor under the sheet. On the tilt motion, reversal must be positive, but not so sudden as to toss the sheet. These factors all influence the choice of the motor characteristics, which inherently are fixed.

The time required to accelerate a motor of squirrel cage design is roughly proportionate to area underneath such torque curves as the speaker has shown. You will note that the shape of this torque curve is such that the maximum point can, in some instances, be moved considerably forward or back with consequent change in the initial torque without materially effecting the area under the curve, that is, without materially effecting the time of reversal. This statement is particularly applicable to plugging service. This feature does enable us to make certain variations in initial torque without materially effecting the total accelerating or reversal time.

On the other hand, the squirrel cage motor provides the simplest and inherently the most rugged construction and with full voltage starting requires a minimum of control. The progress in design has fortunately permitted the application of the squirrel cage motor to very severe duty cycles, in spite of these limitations. We have recently completed some very detailed tests on motors our company furnished for sheet mill catcher service, and these tests show the motors performing most satisfactorily the severe duty cycle to which they are subjected.

We should not neglect to point out the significance of this development as regards the control equipment. The more severe the duty cycle on the motors, the more is demanded from the control. A.C. contactors are now called on to meet the same severe requirements formerly imposed only on D.C. equipment. Forty operations a minute will not take very long to expose any weakness in design.

The speaker is to be congratulated for a very excellent paper and, with his company, for contributing most substantially to a development which holds much promise.

J. W. Bates: I think that after listening to this unusually instructive paper by Mr. Henderson, all of us feel that we have added to our knowledge of the factors entering into the design of A.C. motors. So much has been said regarding their actual design that it hardly seems advisable to attempt to add to it. Some points leading up to the adoption of the present type of motors may be of interest.

For years we engineers have automatically associated reversing plugging service for auxiliaries, with D.C. motors. Following this line of thought D.C. motors were tried out. As the use of variable speed motors to secure a change in chain speed with various roll sizes was considered advisable, variable speed D.C. mill motors were installed. In spite of the high conversion efficiency of D.C. mill motors they were unsatisfactory even at base speed. The reversal was too slow. At first thought this does not seem to agree with our understanding of the torque characteristics of D.C. motors. However, the chief difficulty was the impracticability of using series motors. To obtain the constant speed characteristics required it was necessary to use a motor with shunt characteristics. This in turn, necessitated the use of resistance steps to limit the current inrushes to values consistent with good commutation. The new design of A.C. motor described will deliver as much torque, with the same WR^2 as a D.C. mill motor (shunt), when the current inrush is limited to 250% of full load current. Under these conditions, the added time due to the use of accelerating contactors makes the D.C. motor actually slower in reversing the load than the A.C. motor.

This would seem to indicate the opening of an entire new field to the A.C. motor. However, it should be remembered that, for the present, this holds only for loads with a relatively small WR^2 and a low frictional load. A.C. motors with a high resistance have relatively low losses on starting and high losses on running, so that when the running load is high it becomes difficult to use high resistance motors without encountering overheating.

D. I. Bohn: I enjoyed the paper very much because we have many D.C. auxiliary applications which could be handled by induction motors. However, the lack of flexibility mentioned by Mr. Anderson prevented their being considered.

A Member: What are the speeds of the motors you furnished the American Sheet & Tin Plate Company?

E. W. Henderson: Speeds furnished the American Sheet & Tin Plate Company were 375 R.P.M. (syn.) for 25 cycle circuits and 450 R.P.M. (syn.) for 60 cycle supply.

If you plot the loss on the motor during acceleration against time, or reversal loss against time, the latter loss characteristic will run something like this:

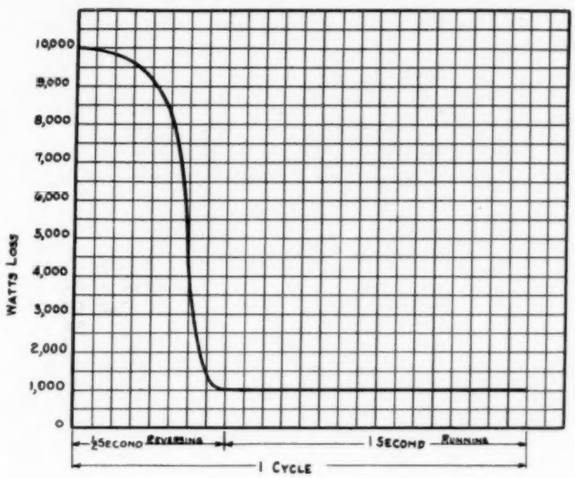


FIG. A.

Figure A includes the reversing and running time. You will notice this shows one-half second for reversal and one second for running. It is extremely important to keep the reversing loss down because even although it lasts only half the time, it amounts ordinarily to very much more than the running loss. We chose 450 R.P.M. because we think we can keep the losses at 450 R.P.M. a regulated amount and thus gain on the reversing period. If you consider 600 R.P.M., the reversing loss for this speed will be $(600/450)^2$ of the 450 R.P.M. loss assuming the same WR^2. This amounts to an increase of 80%.

J. I. Kaspari: You stated the losses in rotor on reversing were four times what they were on starting. Does that hold true for the stator too; that is, for the whole motor as well?

E. W. Henderson: As to the losses in the stator: the stator takes from the supply line a current proportional to the rotor current so that approximately proportionate losses occur in each for any given condition. The iron loss increases the stator loss and the no load current effects the total stator copper loss, so that the stator losses, while not exactly proportional, are nearly so under reversing conditions.

J. I. Kaspari: Why stop at 450 R.P.M., or what was the determining factor in deciding the minimum speed?

E. W. Henderson: You can drop below 375 for 25 cycle, but 375 seems as low a speed as you want to consider. To decrease the speed below 450 R.P.M. for 60 cycle motors, while possible, is probably not economical. The losses increase if too many poles are used and other design difficulties arise.

J. I. Kaspari: What is the reason 18-poles are not and 16-poles are, a good motor?

E. W. Henderson: If you could go down to zero that would be ideal from the reversing loss standpoint. I wouldn't swear to 450 R.P.M. The best speed is somewhere near there. You can't go below a certain value without the constant losses going too high. This part (the running part of Figure A) of the curve overbalances this (the reversing) part.

A Member: What are the details as regards reversing table?

E. W. Henderson: Perhaps Mr. Bates can give that.

J. W. Bates: I do not know just what is meant by "control details". If all the "details" of the control were to be described, it would require considerable time. I will be glad to attempt to give the details of any particular point if that is requested.

A Member: Do you have limit switch or some other device?

J. W. Bates: Yes, there is a drum type limit switch on each table, the limit switches being driven from the gear reduction unit on the two tilt motions. There is also a mechanical trigger on the catcher's table that operates a hatchway limit switch.

A Member: On the reversal of the table proper, what controls the sequence?

J. W. Bates: The complete operation is under the control of the sheet. When the sheet or pack goes through the mill it depresses the mechanical trigger which through the two drum type limit switches tilt the catcher's table, reverse both chains, and then tilt the roller's table. When the pack leaves the trigger going back over the mill it lowers the roller's table, reverses the chains, and lowers the catcher's table. The cycle is then repeated until the master switch is placed in the "run-off" position which causes the pack to be discharged on the catcher's side of the mill. The "staggered" method, whereby the tables do not move together is done, not to simplify the control, but to secure a product of greater flatness.

A Member: Photo electric cell?

J. W. Bates: A photo electric cell can be used for a trigger. It does not have to be used. It so happens that, unless an installation has been made in past several weeks, no photo electric cells have been used for this purpose. The difficulties arise in finding a suitable place to mount the relay.

E. W. Henderson: Everything is controlled from the catcher's table (see Fig. 3). Take a sheet going through here; it operates this trigger switch, as that switch goes down it sets up a reversing circuit and the moment the trigger flies up the tilting motor is thrown on the line and the table starts to tilt. At the same instant the conveyor motors are reversed. As the catcher's table rises it operates a limit switch through a drum type controller shown here (see Fig. 3) driven by a chain from the crank motion used in tilting. This operates to tilt the roller's table and bring it to the "up" position ready to receive the pack as it passes back over the mill. The sheet or pack traveling back over the trigger depresses it in the opposite direction. When it is released it operates to "drop" the catcher's table. As the catcher's table descends it operates its drum controller again to "drop" the roller's table. As the roller's table goes down it operates a drum type relay (see Fig. 2) to reverse the conveyor motors and operate the chains again in a forward direction. By the time the table is down the piece is ready to go into the mill. There are probably one hundred ways this sequence might be accomplished.

A Member: What were the horsepower ratings of these motors?

E. W. Henderson: That is a ticklish question. We do not ordinarily put any horsepower on the name plate. The horsepower is not of much consequence.

As far as the load on the conveyor is concerned the horsepower load is probably not over one-half H.P., certainly not over one H.P. It is a matter of getting a torque to reverse a motor. So far as the tilting operation goes, the horsepower output at the start is zero. It starts from rest and makes only 2½ or 3 revolutions; so that it never runs under load anyway. We prefer to rate them in torque rather than by horsepower.

W. Anderson: The photo electric cell has been successfully applied in place of the flag switch. The advantage they hope to gain is a saving of several inches in overtravel. The application has been successfully made, although there are some difficulties which have yet to be overcome.

W. B. Shirk: I want to congratulate Mr. Henderson on the very excellent paper he has presented here this evening.

I am not a design engineer so therefore it is my duty to coordinate the various parts of the equipment in order to obtain a well balanced installation.

Everyone realizes that if your control is sluggish the motors have less time to perform their function. If you design the control so as to incorporate fast operating contactors and relays the duty on the motor will be reduced.

The motor loss formula which Mr. Henderson has explained does not mean motor losses to me but rather the horsepower seconds stored energy in the rotor at free running speed.

E. W. Henderson: That loss is a coincidence. It works out that the loss in the rotor, in the case of accelerating an induction motor rotor, is exactly equal to the stored energy which is there when you get it up to speed. In other words, you can make the transformation at an overall efficiency of 50%. The expression given for the accelerating loss is derived from the constants for the induction motor. For a full explanation I would refer you to Vol. XLV of the A. I. E. E. Transactions, page 369. I shall not attempt to go through it here.

W. B. Shirk: I thought it would be well to bring out the basis on which Mr. Henderson's formula was derived due to the fact that many of you gentlemen figure the size of flywheels when the occasion arises.

C. O. Franklin: Generally speaking, do you consider 25 cycles more suitable for this type of motor than 60 cycles on account of the fact that lower speeds are obtained with a fewer number of poles, or are there features of design which make 25 cycles objectionable?

E. W. Henderson: The 25 cycle motor at 375 R. P.M. is undoubtedly better than the 60 cycle motor at 450 R.P.M. The losses in the 25 cycle motor are less, both during reversing and running.

A Member: Are there any special characteristics of the D.C. generator which you use for braking?

E. W. Henderson: There are no special features other than that a voltage is chosen that is not only practical but economical. To have a generator for each motor is impractical and to use the ordinary D.C. supply voltage would require series resistances and large rheostatic losses. I feel it is not practical unless you have a large number of similar motors which you wish to stop simultaneously. Then you can design a generator to give you a voltage which is suitable for the load. The generator is very intermittently rated. It is small. It is used during braking time only so that it is not expensive. It will ordinarily work out that 440 volt A.C. motors (induction) will require approximately a 110 volt D.C. braking generator.

ITEMS OF INTEREST

PERSONNEL CHANGES

▲

Ambrose N. Diehl, a vice president of the U. S. Steel Corporation in New York, has been made president of the Columbia Steel Company, the corporation's Pacific Coast subsidiary, San Francisco, California.

Mr. Diehl came up through the ranks first at the Duquesne Works of the Carnegie Steel Company, then he became vice president of the Carnegie Steel Company and in August, 1930, was made a vice president of the U. S. Steel Corporation with offices in New York.

Mr. Diehl has a host of friends in the Steel Industry throughout the United States who will all be pleased to learn of his new executive capacity.

▲

Carl V. Dodge, manager of roll and steel casting sales for the United Engineering & Foundry Co., Pittsburgh, has been elected a vice president of the company. He has been identified with the production and sale of rolls and steel castings since 1904.

W. G. Ellis, representing The Ohio Electric Mfg. Co., makers of Lifting and Separation Magnets and of Fractional Size Motors, has moved his office to 1473 Broad Street Station Building, Philadelphia, Pa.

▲

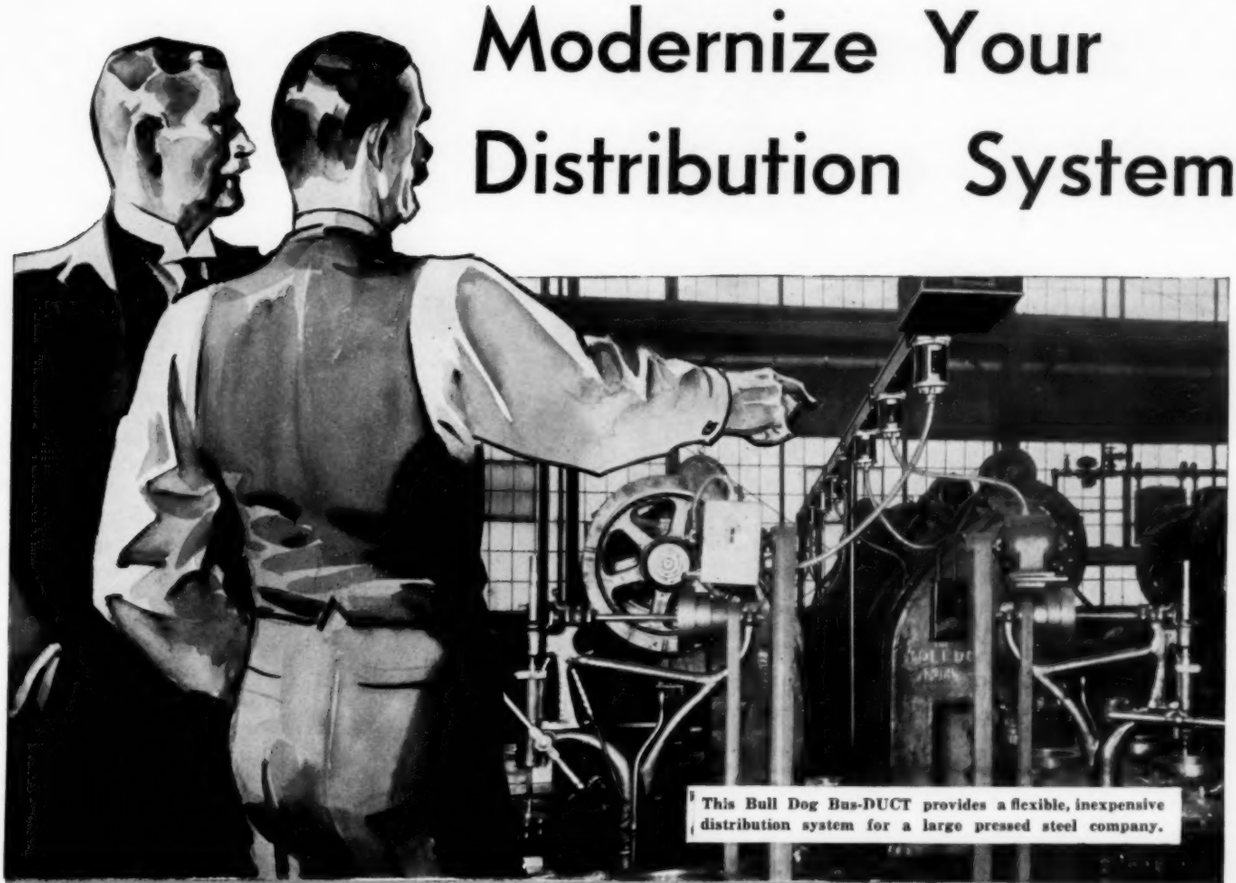
Fafnir Bearing Co., New Britain, Conn., manufacturer of ball bearings, has moved its office at Detroit from 120 Madison avenue to 502 New Center Building; at Cleveland from the Swetland Building to 407 Union Building, 1836 Euclid avenue; at Los Angeles to 417 West Pico street. Distribution of Fafnir bearings in New York and the Metropolitan district is now in the hands of the L. C. Biglow Company, 250 West Fifty-fourth street. R. W. Powell has been placed in charge of the company's sales in Northern Ohio, at the Cleveland office.

▲

T. A. Kenny, formerly sales engineer with the Rutherford & Uptegraff Company of Pittsburgh, Pa., is now with the Superior Engineering Company, of Pittsburgh, Pa., and will specialize on the sale of the Jewell and Weston lines of electrical measuring instruments.

NOW IS THE TIME TO

Modernize Your Distribution System



This Bull Dog Bus-DUCT provides a flexible, inexpensive distribution system for a large pressed steel company.

Put BULL DOG on the Job

Right now, when you have the opportunity to thoroughly overhaul your electrical equipment, you will probably discover locations where a safer, more efficient and flexible system of control would be desirable. We will be glad to show you how a Bull Dog Distributing System will fit into your production scheme. The cost installed is less than for inferior products. Maintenance expense is lower. It provides for future changes and expansions and its mobile flexible construction assures 100% salvage.

Put BULL DOG on the Job.

BULL DOG ELECTRIC PRODUCTS COMPANY
Detroit, Michigan

OVER 25 YEARS OF RESEARCH AND DEVELOPMENT

R. F. Clark of the Superior Engineering Company of Pittsburgh, district manager of the Jewell Electrical Instrument Company for the past thirteen years, has been appointed district manager for the combined Jewell and Weston lines of electrical measuring instruments.

▲

H. J. Ritter, assistant secretary of Norma-Hoffmann Bearings Corporation, Stamford, Conn., has also been made sales manager of the organization. To his new duties he brings the experience of years as sales engineer and, later, as manager of the New York sales office, for the corporation.

▲

WITH THE MANUFACTURERS

▲

The Hyatt Roller Bearing Company has just issued a very attractive book which contains the complete description of how their bearings are manufactured. This book commemorates forty years of service to the Industry by the Hyatt Company.

▲

Electric Controller & Manufacturing Company, Cleveland, O., announce a new heavy duty lifting magnet. This magnet is 39" in diameter and is of intermediate size for use with overload, crawler, gasoline or locomotive type cranes in foundries, scrap yards, railway stores and maintenance of way departments, warehouses and similar applications where the capacity of the crane will permit the use of a magnet of greater lifting capacity than the present magnets in the 30"-39" range.

▲

The Timken Roller Bearing Company at Canton, O., has just issued a 28-page booklet, which illustrates the progress of Timken Bearings starting with 1898 and ending with 1932.

▲

The April issue of Trumbull Cheer contained a very interesting article in connection with the Association of Iron and Steel Electrical Engineers' 25-year growth. Trumbull Cheer also was 25 years old in April.

▲

Allis-Chalmers Mfg. Co. has just issued a transformer bulletin No. 3018 covering Combination—Expansion Tank and Relief Device with numerous new and novel features.

▲

The May issue of Exide Iron Clad Topics contained a very interesting article in connection with the Association of Iron and Steel Electrical Engineers' Twenty-fifth Anniversary.

▲

Bulletin 1024 issued by the C. J. Tagliabue Mfg. Company presents an interesting story in connection with the new TAG Steam Operated Controller. For complete description of this controller write the C. J. Tagliabue Mfg. Company, Brooklyn, N. Y.

POSITION WANTED

▲

An electrical engineer with 22 years of experience in Steel Mills, industrial generation and substation engineering is open for a position in engineering or technical sales.

He is a graduate of Columbia University and has been in responsible charge of electrification at some of our largest mills and power stations and been associated with consulting engineers and utilities. He has had considerable experience as a salesman and has a large circle of business friends.

Address 102, 1010 Empire Building, Pittsburgh, Pa.

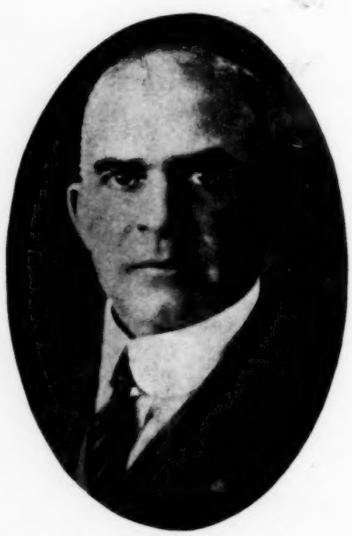
▲

OBITUARY

▲

Mr. B. W. Gilson, Electrical Superintendent at the Ohio Works and Superintendent of Light and Power, Youngstown District, of the Carnegie Steel Company, Youngstown, Ohio, died at his home Wednesday evening, April 27, 1932.

Mr. Gilson became affiliated with the Carnegie Steel Company at Homestead in 1892 in the Electrical Department under the supervision of the late A. C. Dinkey. In July, 1894, when Mr. S. S. Wales was appointed Chief Electrician of the Ohio Works,



B. W. GILSON

Mr. Gilson accompanied him to work on Construction. He made steady progress in that plant and at the death of the Electrical Superintendent, Mr. P. Brown, Mr. Gilson succeeded him and held that responsibility until the time of his death.

Mr. Gilson was President of the Association of Iron & Steel Electrical Engineers in 1920 and has served on many National Committees of the Association. We take this opportunity to extend our sympathy to the family and friends of Mr. Gilson. The A. I. & S. E. E. in losing him lost one of its most loyal and staunch supporters.